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**THERMAL ANALYSES OF PLUTONIUM MATERIALS  
IN BRITISH NUCLEAR FUELS, LTD., CONTAINERS**

**by**

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## EXECUTIVE SUMMARY

Plutonium materials, including both metal and oxide forms, are placed in nested stainless steel containers for long-term storage. Department of Energy (DOE) Standard DOE-STD-3013-96 provides criteria for packaging plutonium metals and oxides for long-term storage, and among these criteria is a maximum temperature limit of 100°C (212°F) for alpha-phase metal. Although other temperature limits are not currently specified in the order, there exists substantial interest within the DOE complex about the temperatures that are associated with storing various material forms.

We have performed thermal analyses to address the questions of maximum temperature, temperature distribution, and heat-transfer modes for both plutonium metal and PuO<sub>2</sub> inside the British Nuclear Fuels, Ltd., (BNFL) container system. The BNFL container system includes three separate, nested containers: a sealed outer container, a sealed inner container, and a convenience container for holding the plutonium materials.

We included plutonium metal in the forms of an ingot and buttons; the buttons represent a nominally conservative condition. We also considered PuO<sub>2</sub> with varying density. For the base-case situation, we assumed the fill gas for the containers was helium for metal storage and air for oxide storage. Through sensitivity studies, we have addressed additional questions concerning the impact on temperatures of various structures/objects surrounding the container, changes in specific power, alternative fill gases, and contact resistances between the nested containers. We considered specific powers that produced total powers between 15 and 30 W when the container held the maximum amount of material—4.4 kg (9.7 lb<sub>m</sub>) of plutonium metal or 4.99 kg (11.0 lb<sub>m</sub>) of PuO<sub>2</sub>. Alternative fill gases for metal storage included air and argon. In all cases, the final heat-sink temperature was 26.7°C (80°F).

The analysis methodology used a nodal network representation of the metal/oxide, the container system, and the surroundings. The nodal network representation divides the problem into a number of separate volumes or nodes that are connected by thermal resistances. The thermal resistances describe conduction, convection, and radiation heat-transfer modes. Our current analyses evaluate steady-state conditions, but the methodology can be extended to describe transient scenarios.

We analyzed the following cases: a single container suspended in air, a single container sitting on a flat plate, a single container in a storage drum, and an array of storage drums (with BNFL containers) in a cabinet. We assumed that the ultimate heat sinks for all cases were provided by 26.7°C (80°F) room air and walls; heat rejection from the modeled geometries to the room air and walls took place only through the processes of convection and radiation heat transfer. These external conditions for the container represent idealized situations that may exist for the container from the time it is loaded with the plutonium material until it is placed in storage. We based these configurations on the interim storage system at Rocky Flats Environmental Technology Site.

Based on a fully loaded container with a 4.4-kg (9.7-lb<sub>m</sub>) metal ingot generating 15-W decay heat, the calculated maximum temperatures indicate that the Rocky Flats

implementation of the BNFL container system with a Vollrath convenience jar leads to metal temperatures that approach the 100°C limit in the 3013 standard for the case of the container in air. The vault storage systems can drive the temperature of the stored metal beyond the specified limit. Our analyses further indicate that the cases with two plutonium metal buttons [4.4 kg (9.7 lb<sub>m</sub>) total] result in slightly higher temperatures [~10°F (~5.6°C)] than the corresponding cases with the idealized ingot. Another observation from the results is that the outside surface of the containers is generally in excess of 100°F (37.8°C).

For metal storage, the fill-gas composition inside the storage containers has a big effect on the maximum temperatures. Changing from helium to air (we used air to represent all gases consisting primarily of nitrogen and varying amounts of oxygen) increased the maximum temperature for the case of two buttons and the container on a plate by ~138°F (~76.4°C). Changing to argon increased the maximum temperature by ~166°F (~92.1°C). Based on the thermal performance, we believe that helium should be the preferred fill gas for the containers storing metal.

We used the analyses to investigate the relative contributions of conduction, convection, and radiation heat transfer from both the stored material and the outside of the container. Conduction and convection provide the principal means of transporting heat through the container and surrounding structures. The variations in the four basic cases of external structures and the changes in the fill gas inside the containers primarily explored the relative importance of conduction and convection heat transfer. Clearly, steps should be taken in the design of storage systems to enhance these two heat-transfer modes.

Radiation heat transfer accounted for 7–10% of the heat removal from the plutonium metal and 12–22% of the heat removal from the outside of the container, depending on the configuration of the stored material and conditions outside the container. While radiation heat transfer is a relatively small fraction of the total heat transfer, the relatively high temperatures of the stored plutonium metal make radiation heat transfer an important part of the total heat transfer. For the base-case emissivities, radiation heat transfer lowers the maximum temperature of the plutonium metal (in the form of two buttons) by 11.3°F (6.3°C) relative to the analysis without radiation heat transfer. Surface treatments of the various containers can impact the emissivity of the surface and thereby affect the radiation heat transfer. Reasonable variations in surface treatment (and hence emissivity) can change the maximum temperature by as much as +3.2°F (+1.8°C) by decreasing the emissivity of the stainless-steel surface or by -8.3°F (-4.6°C) by increasing the emissivity. We also ran sensitivity cases to determine the effect of reasonable changes in the emissivity of the plutonium-metal surface.

Plutonium oxide in the BNFL container system can far exceed 212°F (100°C); however, the 3013 standard does not specify a temperature limit for oxide. We did calculations for oxide-powder densities of 2.00, 2.72, 3.02, 4.54, and 6.70 g/cm<sup>3</sup> and for specific powers of 3.006 W/kg and 6.012 W/kg. The BNFL convenience jar holds only 3.67 kg of oxide at 2.00 g/cm<sup>3</sup>; for 2.72-g/cm<sup>3</sup> density, 4.99 kg of oxide exactly fills the convenience jar. The volume of oxide at 3.02, 4.54, and 6.70 g/cm<sup>3</sup> is determined by setting the mass to 4.99 kg, and the convenience container is only partially full. The two

specific powers correspond to 15.0 and 30.0 W for 4.99 kg of oxide. The calculations produced the following maximum temperatures:

PuO <sub>2</sub> Density	Specific Power	
	3.006 W/kg	6.012 W/kg
2.00 g/cm <sup>3</sup>	217.9°F (103.3°C)	350.7°F (177.1°C)
2.72 g/cm <sup>3</sup>	243.2°F (117.4°C)	399.6°F (204.2°C)
3.02 g/cm <sup>3</sup>	246.7°F (119.3°C)	406.7°F (208.1°C)
4.54 g/cm <sup>3</sup>	250.8°F (121.6°C)	414.1°F (212.3°C)
6.70 g/cm <sup>3</sup>	220.3°F (104.6°C)	352.5°F (178.1°C)

Because of the thermal coupling of the oxide to the container and because of the oxide thermal conductivity, the 6.7-g/cm<sup>3</sup> oxide had a lower maximum temperature than the 4.5-g/cm<sup>3</sup> oxide. The thermal conductivity of the oxide is a large uncertainty, and there are very few data supporting the values used in the analyses. In lieu of measured data, we used correlations to specify an effective thermal conductivity for the powder. The thermal conductivity is affected by the porosity of the powder, the particle size of the oxide, and the individual thermal conductivities of the particles and the cover gas. Small oxide-particle sizes adversely impact the oxide-powder thermal conductivity.

In general, the temperatures of the stored plutonium metal are relatively high. If the containers are loaded with sufficient metal materials to produce 15 W, it appears that engineered features are required both inside and outside the container to enhance heat removal and to ensure that the temperature limit for alpha-phase material specified in the 3013 standard is met. Because the calculated temperatures for stored plutonium metal with 15-W decay heat approach the 212°F (100°C) limit in the 3013 standard, experimental data should be obtained for storage containers with metal, and the data should be used to assess the accuracy of the calculational methodology. Other studies are required to determine if the calculated temperatures for the PuO<sub>2</sub> can have detrimental affects on the oxide and containers during long-term storage. Experimental data should be obtained to reduce the uncertainty in the thermal conductivity of the oxide powders.

## **THERMAL ANALYSES OF PLUTONIUM MATERIALS IN BRITISH NUCLEAR FUELS, LTD., CONTAINERS**

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### **ABSTRACT**

The Department of Energy (DOE) plans to place plutonium materials in long-term storage using nested stainless steel containers. Thermal conditions within the containers are important in terms of current standards and studies related to long-term stability. DOE Standard DOE-STD-3013-96 provides criteria for packaging plutonium metals and oxides for long-term storage. Among the criteria is a maximum temperature limit of 100°C (212°F) for alpha-phase metal. Although other temperature limits are not currently specified in the standard, there exists substantial interest within the DOE complex about the temperatures associated with storing various material forms for establishing the expected thermal conditions for long-term storage.

We performed thermal analyses of a plutonium ingot, two plutonium buttons, and PuO<sub>2</sub> powder of various densities inside the British Nuclear Fuels, Ltd., (BNFL) container system. These studies are limited to numerical modeling of expected conditions. Future experiments will provide data against which we can benchmark these analyses. We analyzed the following cases: a single container suspended in air, a single container sitting on a flat plate, a single container in a storage drum, and an idealized array of storage drums in cabinets. In all cases, the ultimate heat sink is room air and walls at a specified temperature of 26.7°C (80°F). We also ran a variety of sensitivity cases, including changes in specific power and cover gas. Based on a fully loaded container [4.4 kg (9.7 lb<sub>m</sub>) metal generating 15-W decay heat (3.41 W/kg Pu)], the calculated maximum temperatures from our base-case analyses indicate that the current design of the BNFL container system leads to metal temperatures that approach the 100°C limit in the 3013 standard. The vault storage systems can drive the temperature of the stored metal beyond the specified limit. The base-case analyses assumed that the fill gas inside the containers is helium. Air (used to represent nitrogen-rich gases) and argon result in significantly higher temperatures. Plutonium oxide in the BNFL container system can far exceed 100°C. Another observation from the results is that the outside surface of the containers is generally in excess of 37.8°C (100°F.)

## 1.0. INTRODUCTION

Recent events, including the downsizing of the nuclear weapons stockpile and the reduction and consolidation of facilities involved in nuclear weapons manufacturing, have resulted in a significant inventory of plutonium materials that must be stored safely for a long period before the final disposition of the material. These changes in the inventory destined long-term storage increase the need for expanded storage capacity and standardized containers. The Department of Energy (DOE) has recently issued a revised standard DOE-STD-3013-96 (Ref. 1, and subsequently referred to simply as the “3013 standard” or with the adjective “3013”) specifying the packaging criteria for plutonium metal and PuO<sub>2</sub> in long-term storage. The 3013 standard provides the following constraints relative to the thermal behavior of the stored materials:

1. The power generation from a single container shall be less than 30 W.
2. The mass of plutonium metal in a single container shall not exceed 4.4 kg (9.68 lb<sub>m</sub> [sic]).\*
3. The mass of PuO<sub>2</sub> shall not exceed 5.0 kg (10.97 lb<sub>m</sub> [sic]).\*\*
4. The steady-state temperature of stored alpha-phase plutonium metal shall not exceed 100°C (212°F).

The above criteria limit the acceptable thermal response of the stored plutonium materials to storage conditions. The standard provides additional criteria, such as limits to preclude pyrophoric reactions and to restrict gas adsorption in oxides [loss-on-ignition (LOI) limit], but these additional limits generally do not impact the thermal analysis of material storage.

Because several sites in the DOE complex need to renovate or build nuclear-materials storage facilities, there is a desire to standardize the packaging across the complex to facilitate storage, transportation, and handling of the packaged materials. British Nuclear Fuels, Ltd., (BNFL) has proposed a container packaging system as a candidate for the standard container. This system, subsequently referred to as the BNFL container, consists of a relatively thick-walled outer container and a somewhat lighter inner container, both of which are welded closed. Additionally, the BNFL container includes a BNFL convenience jar, although individual sites may opt for a different convenience container.

The combination of the 3013 thermal limit, the design of the BNFL container, and expected new or renovated storage facilities requires that thermal analyses be performed to ensure that the limits are met for each facility.

The Rocky Flats Environmental Technology Site (Rocky Flats) is one of the DOE sites consolidating its plutonium inventory into a new vault facility inside an existing building; in the process, Rocky Flats tentatively has adopted the BNFL container. They

\* A more precise conversion of 4.4 kg is 9.70 lb<sub>m</sub>.

\*\* A more precise conversion of 5.0 kg is 11.02 lb<sub>m</sub>.

will use the BNFL convenience container for storing oxides and the Vollrath 88010 jar as a convenience container for plutonium metal.

The Rocky Flats approach to storage in the new vault is to load the nested BNFL containers with nuclear materials inside a glove box system. Once a container is removed from the glove box, the container is placed in a commercial 10-gal. drum with a spider assembly to prevent placing more than one container in the drum. Inside the vault, the drum-and-container assembly is placed inside a closed cabinet.

In this report, we investigate the thermal behavior of the BNFL container system in several different external conditions that represent idealized situations that may exist for the container from the time it is loaded with the plutonium material until it is placed in storage. Because of the low temperature limit invoked for alpha-phase plutonium and the lack of specific temperature limits for other material forms, we provide a discussion of plutonium properties and chemistry that can be considered in the context of using the 3013 containers. Then we proceed to describe the specific thermal issues to be addressed in the analyses, the configurations to be analyzed, and the analytical tools. We conclude by presenting the analysis results and conclusions.

Because the community involved in the storage of plutonium materials appears to work commonly with a mixed set of units [dimensions in either the International System of Units (SI) or Engineering units, material density in g/cm<sup>3</sup>, and temperatures in °F], this report will adhere somewhat to that convention. In particular, temperatures will be given in °F in figures. Additionally, the generic term “metal” without any adjective will mean plutonium metal. Similarly, oxide without any adjective will mean PuO<sub>2</sub>.

## 2.0. SUMMARY OF PHYSICAL LIMITS FOR PLUTONIUM METAL

We met with Los Alamos plutonium experts<sup>2</sup> to discuss plutonium properties and chemistry from a safety perspective and reviewed material concerning plutonium properties in Refs. 3 and 4. A summary of the discussion and review appears in Appendix A. The 212°F (100°C) temperature limit specified in the 3013 standard for storing α-phase plutonium metal appears to be based on avoiding the α-β phase transition. There is a ~9% volume expansion (~3% linear expansion) that the metal undergoes as it transitions from α to β phase. Cycling back and forth through the α-β phase transition results in a realignment in the grain structure in the metal because of the differences in the crystalline structure. The realignment in grain structure produces micro-cracking of the metal and ultimately loss of integrity of the shape as the bulk metal. Because of these changes associated with the α-β phase transition, the temperature limit specified in the 3013 standard for α-phase plutonium metal should not be relaxed without careful study of the impact of the phase change on container integrity and on long-term storage and retrieval operations.

For δ-stabilized plutonium and if the 212°F (100°C) limit for α-phase plutonium is modified or removed, there are chemical reactions with threshold temperatures that could serve as thermal limits starting at ~250°F (121°C) that apply regardless of the crystalline structure of the metal. The impacts of these chemical reactions are adverse only if hydrogen and oxygen or nitrogen are present inside the containers. Hydrogen can be produced through radiolysis of contaminants such as machine oil left behind

during the manufacture of the containers or of plastic materials used to contain radioactive contamination. Oxygen or nitrogen could be introduced through the fill gas at the time the container is sealed for storage or through leaks. Because of these chemical reactions, nitrogen is not an inert gas for storing plutonium metal.

To avoid pyrophoric reactions in the event that the fill gas contains oxygen or when the container is opened in an oxygen environment after storage, the temperature limit of 302°F (150°C) for the plutonium is applicable. This limit prevents pyrophoric reactions in plutonium metal when the smallest dimension is  $\leq$  1 mm (0.04 in.). If the assumption that the fill gas is inert is valid, then this limit would apply only at the time the container is opened in the presence of oxygen.

If the phase transitions are ultimately shown to be unimportant in terms of container integrity and long-term storage and retrieval of the plutonium, and if the impact of the chemical reactions is removed through elimination of contaminants, plastics, oxygen, and nitrogen from inside the containers, then the ultimate temperature limit for the storage of plutonium is set by the Pu-Fe eutectic melting point. This melting point of 1184°F (640°C) represents a failure mode for the container when steel and plutonium are in contact at or above this temperature.

### **3.0. THERMAL ISSUES AND ANALYTICAL APPROACH**

The 212°F (100°C) temperature limit specified in the 3013 standard for the storage of  $\alpha$ -phase plutonium metal drives the requirement to determine the maximum temperature of plutonium metal placed in storage. A necessary extension of this requirement is to calculate the temperature distribution for various shapes of the metal parts in the storage container. Further, the calculations need to include the effects of external structures and boundary conditions on the temperature distribution inside the plutonium metal. A logical extension of these analyses is to determine the temperature distributions of stored PuO<sub>2</sub> to facilitate an understanding of potential problems related to the storage of oxide. These problems include outgassing of adsorbed gases or contaminants such as solvents in the powder and possible chemical reactions and physical changes that could impact the container adversely.

Plutonium metal in storage can be in the forms of an ingot, a button, or small, randomly-shaped pieces. (A button has an approximate shape of a spherical segment—one curved surface and one flat surface.) The small pieces have large surface-to-volume ratios and may result in relatively large contact areas to the container. Large surface-to-volume ratios enhance convection and radiation heat transfer. A large contact area enhances conduction heat transfer. These effects should reduce the temperatures of the plutonium metal. In contrast, the ingot and button forms should provide upper bounds for the maximum temperatures because of their smaller surface-to-volume ratios and potentially small contact areas with the container. The calculations in this report will consider maximum-allowed mass of plutonium metal [4.4 kg (9.70 lb<sub>m</sub>)] in the form of a single ingot or a pair of buttons of equal mass. The dimensions and orientation of the ingot were specified to reduce both the contact area between the ingot and the convenience jar and the surface area available for convection heat transfer while still allowing for relatively straightforward modeling.

Plutonium oxide is stored in the form of a powder, with densities ranging from 2.0 to  $\sim 6$  g/cm<sup>3</sup> (125–375 lb<sub>m</sub>/ft<sup>3</sup>). Tap densities for fine PuO<sub>2</sub> powders are reported to be in the range of 2–3 g/cm<sup>3</sup> (125–187 lb<sub>m</sub>/ft<sup>3</sup>) (Ref. 5); tap densities are achieved by filling a container with fine powder and then tapping the container on a solid surface. More dense PuO<sub>2</sub> powders can result from various production and separation processes, with  $\sim 6$  g/cm<sup>3</sup> (375 lb<sub>m</sub>/ft<sup>3</sup>) being an upper bound.<sup>6</sup> This report will address temperatures in PuO<sub>2</sub>, and the total mass of oxide will be the maximum allowed in the container [4.99 kg (11.00 lb<sub>m</sub>)],\* provided that the convenience container can hold that amount. The BNFL convenience jar can only hold 3.67-kg (8.09-lb<sub>m</sub>) of PuO<sub>2</sub> with a density of 2.0 g/cm<sup>3</sup>, and our analyses recognized this constraint.

For all of the analyses in this report, the ultimate heat sinks will be 80°F (26.7°C) air for convection heat transfer and 80°F (26.7°C) walls for radiation heat transfer to ensure comparability among the calculations. The following external support structures have been assumed to represent idealized configurations into which a fully loaded container can be placed:

1. The container is suspended in air (subsequently referred to as the **air** case). This case represents the simplest external geometry for the container, and transfer of heat away from the container is restricted to convection and radiation processes.
2. The container is placed on a stainless-steel, circular, flat plate (subsequently referred to as the **plate** case). This case allows conduction heat transfer from the container to the plate. The area and thickness of the plate were arbitrary. We set the area to the shelf space allowed per drum in the cabinet described in item 4 below. The plate diameter and thickness are 0.479 m (18.85 in.) and 4.76 mm (3/16 in.), respectively.
3. The container is placed in a carbon-steel drum, and the drum is suspended in air (subsequently referred to as the **drum** case). This case allows for conduction of heat away from the container to the structure of the drum, but only convection and radiation remove heat from the drum.
4. The container-and-drum assembly from the drum case is placed in a cabinet with solid shelves, sides, back, and front (subsequently referred to as the **cabinet** case). We have assumed that the cabinet holds sufficient drums (4 drums per shelf and 3 shelves per cabinet) and is surrounded by similar cabinets on each side and the back so that the storage location for the drum in our model is a symmetry position that results in all heat being rejected through the front door of the cabinet.

We have based the above four cases for external support structures on idealizations of situations that could occur for the container after it has been loaded with either plutonium metal or oxide. In particular, the drum and the cabinet described in cases 3 and 4 above are based on an interim storage system currently being used at Rocky Flats.<sup>7,8</sup> Rocky Flats places the loaded BNFL container into a commercial 10-gal. drum

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\* This PuO<sub>2</sub> mass of 4.99 kg (11.00 lb<sub>m</sub>) contains 4.40 kg (9.70 lb<sub>m</sub>) of plutonium.

with an internal spider assembly to roughly center the container in the drum and to prevent more than one container from being placed inside the drum. In the storage vault, the container-and-drum assemblies are placed in stainless-steel cabinets. When the cabinets are configured inside the vault, the apparent worse case for thermal behavior has a row of cabinets placed back-to-back and side-to-side.

In addition to the shape of the plutonium metal pieces (or oxide density) and the external support structures described above, there are other choices made during the manufacture and loading of the containers that can affect the temperatures experienced by the stored material. We ran the sensitivity cases for generally a single material configuration (two plutonium metal buttons) and a single support structure (plate) to determine the magnitude of the change in calculated temperatures. We ran the following sensitivity cases:

1. **Specific power (W/kg) of the stored material.** The 3013 standard allows up to 30 W per container. We varied the specific power for both the two plutonium buttons and the PuO<sub>2</sub>. For the maximum allowed mass content, the specific power was varied to yield a total power in the range 15–30 W. The specific power corresponding to 15 W total [3.41 W/kg Pu (1.55 W/lb<sub>m</sub> Pu) or 3.01 W/kg PuO<sub>2</sub> (1.36 W/lb<sub>m</sub> PuO<sub>2</sub>)] is slightly higher than typical values for weapons-grade plutonium.
2. **Contact areas between the inner and outer BNFL containers and between the outer BNFL container and the plate.** This variation was done only for the two plutonium buttons. The drawings for the BNFL containers<sup>9</sup> indicate that the containers have flat bottoms that should match up well with each other and with a support plate; however, design changes, machining tolerances, or warping of the bottoms could significantly reduce the contact areas. These changes were obtained by replacing contact areas with a 1-mm (0.039-in.) gas gap. Because of a misfit between the Vollrath jar<sup>10</sup> used by Rocky Flats to hold plutonium metal and the inner BNFL container, there is a 1.56-mm (0.061-in.) gap between the bottom of the Vollrath jar and the inner BNFL container (this problem is described more fully in the next section).
3. **Alternative fill gases inside the containers.** This variation was done only for the two plutonium buttons. Our base-case analysis assumes that the fill gas is helium, but there have been discussions that indicate that a nitrogen/oxygen mixture or argon could be used as the fill gas for plutonium metal storage. The properties of the gas affect the heat-transfer coefficients between solid surfaces and the gas and conduction/convection within the gas, which therefore affect the heat removal from the plutonium. We used air for simplicity to represent all possible nitrogen/oxygen mixtures because the thermal conductivities of the air, nitrogen, and oxygen are all comparable and significantly less than that of helium. We also did the analysis with argon, because it is a readily available noble gas. Argon has a thermal conductivity that is even less than that of air.
4. **Emissivities of plutonium and stainless steel surfaces.** This variation was done only for the two plutonium buttons. Emissivities of the surfaces have a

significant impact on the magnitude of radiation heat transfer and its contribution to the total heat transfer. The emissivity of the plutonium metal surface is basically unknown and should vary significantly depending on how well the surface is cleaned before loading; for this quantity, we used a nominal value of 0.5 and calculated the effect of changing it to extremes of 0.3 and 0.8. For stainless steel surfaces, normal production processes lead to an emissivity of 0.3, but surface treatments such as developing a thin oxide layer through heat treatment or polishing can readily increase the emissivity to 0.6 or decrease it to 0.2, respectively. We also ran the case with zero radiation heat transfer to determine the overall importance of including radiation heat transfer in the analyses.

The above sensitivity cases do not include all possible changes but rather address some issues of immediate interest that are relatively simple, may be very important, and can be addressed easily in the current design of the containers and the anticipated procedures for loading the containers. The sensitivity studies produce differences in the temperatures for a given set of external structures (the plate case) that can be used additively to determine the approximate effect of the change for other external structures.

#### **4.0. DESCRIPTION OF THE BNFL CONTAINER ASSEMBLY AND THE VOLLRATH JAR**

Rocky Flats has adopted the BNFL outer and inner seal-welded containers for use in their interim storage system. They plan to use the BNFL convenience jar for storing PuO<sub>2</sub> and the Vollrath 88010 jar for storing plutonium metal pieces. Figure 1 shows a vertical cross section of the BNFL inner and outer containers and the BNFL convenience jar; the three containers are cylindrical with circular horizontal cross sections. The dimensions in millimeters, magnitude >1.0, for various features on the containers are based on Ref. 9. Additional dimensions in meters, magnitude <1.0, help to define the node scheme used in the analyses. The outer and inner containers have welded seals that make the containers gastight, containment barriers for material stored inside the inner container. The convenience jar is an optional container that is not gastight, and its outside surface is not necessarily free from radioactive contamination. The convenience jar primarily expedites the loading of the inner container.

We have simplified the figure to facilitate creating the drawing. Features shown are important to the thermal analyses, but additional details, such as the screw threads and the crushable seal for the convenience jar, are not shown. The bottoms of the containers are flat, and the transitions to the sides are smooth curves that are detailed in the lower right corner of the figure. The curved transitions reduce the areas of the flat bottoms and thus reduce the contact (and conduction heat transfer) between the convenience jar and the inner container and between the inner and outer containers. The three nested containers are drawn and subsequently modeled as concentric cylinders about a vertical axis.

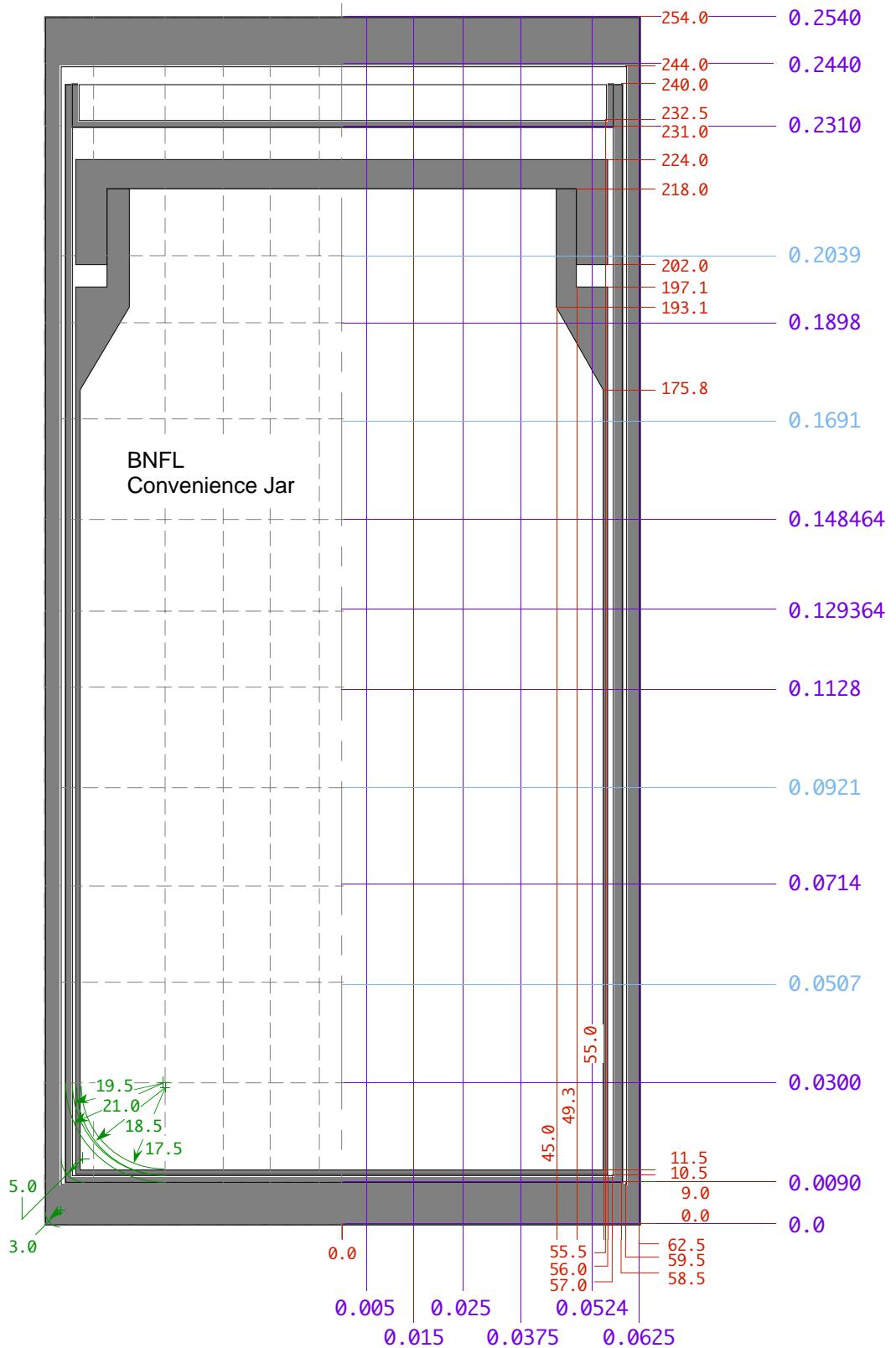


Fig. 1. BNFL inner and outer containers and BNFL convenience jar.

The outer BNFL container is 0.254 m (10.0 in.) high and 0.125 m (4.92 in.) in diameter. The outer container has a bottom thickness of 9 mm (0.35 in.) and a side-wall thickness of 3 mm (0.12 in.). The thickness of the side wall and bottom of the inner container is 1.5 mm (0.06 in.). For the convenience jar, the side-wall and bottom thickness is 1 mm (0.04 in.). The radial gaps between the sides of the convenience jar and the inner container and between the sides of the inner and outer containers are both 1 mm (0.04 in.). All three containers are made from 316 stainless steel (United States specification).

Figure 2 shows the BNFL outer and inner containers together with the Vollrath 88010 jar. The dimensions for the Vollrath jar came from Ref. 10; we have converted the dimensions to SI units. The Vollrath jar is 0.1356 m (5.339 in.) high and 0.1048 m (4.125 in.) in diameter; the material is 304 stainless steel. As before, we have simplified the representation of the Vollrath to facilitate creating the drawing. In particular, there is an expanded bulge in the side wall of the Vollrath that limits how far down the lid sits. Also, there are details of a handle in the lid that we have chosen to ignore. The lower left corner of Fig. 2 shows the details of the smooth, curved transitions between the bottoms and the side walls of the three containers. Figure 3 shows an expanded detail of these transitions. The flat portion of the bottom of the Vollrath is 42.9 mm (1.689 in.) in radius, whereas the radius of the flat bottom of the inner BNFL container is only 37.5 mm (1.476 in.). This difference in the size of the flat bottoms of the Vollrath jar and the BNFL inner container results in an interference that prevents the Vollrath from sitting on the bottom of the inner container. The assumption that the axes of the Vollrath and the inner BNFL container coincide results in a gap between the two bottoms of 1.564 mm (0.062 in.).

## 5.0. DESCRIPTION OF THE PLUTONIUM MATERIALS

To reduce the complexity of the model for the initial calculations for plutonium metal, we assumed that the ingot was a right-circular cylinder standing on its end in the middle of the Vollrath jar shown in Fig. 2 (axes of the ingot and the containers coincide). The constraints on the dimensions of the ingot were

- a total mass of 4.4 kg (9.70 lb<sub>m</sub>),
- a density of 19.86 g/cm<sup>3</sup> (1240 lb<sub>m</sub>/ft<sup>3</sup>) (Ref. 4),
- a length less than the height of the Vollrath jar,
- a radius that coincides with a boundary between nodes in the model, and
- a minimum contact area with the bottom of the Vollrath.

The resulting dimensions were a diameter of 0.05 m (1.97 in.) and a length of 0.1128 m (4.44 in.). The elevation of the top of the ingot is 0.1257 m in the figure, and the radius is 0.025 m. The analyses used only this shape and orientation for the ingot. The orientation of the ingot is not the worst case in terms of temperatures because the contact area with the bottom of the Vollrath is still relatively large; the worst case would tilt the ingot to reduce the metal-to-metal contact to two or three point contacts with essentially no area, thereby forcing the heat removal to be through the gas.

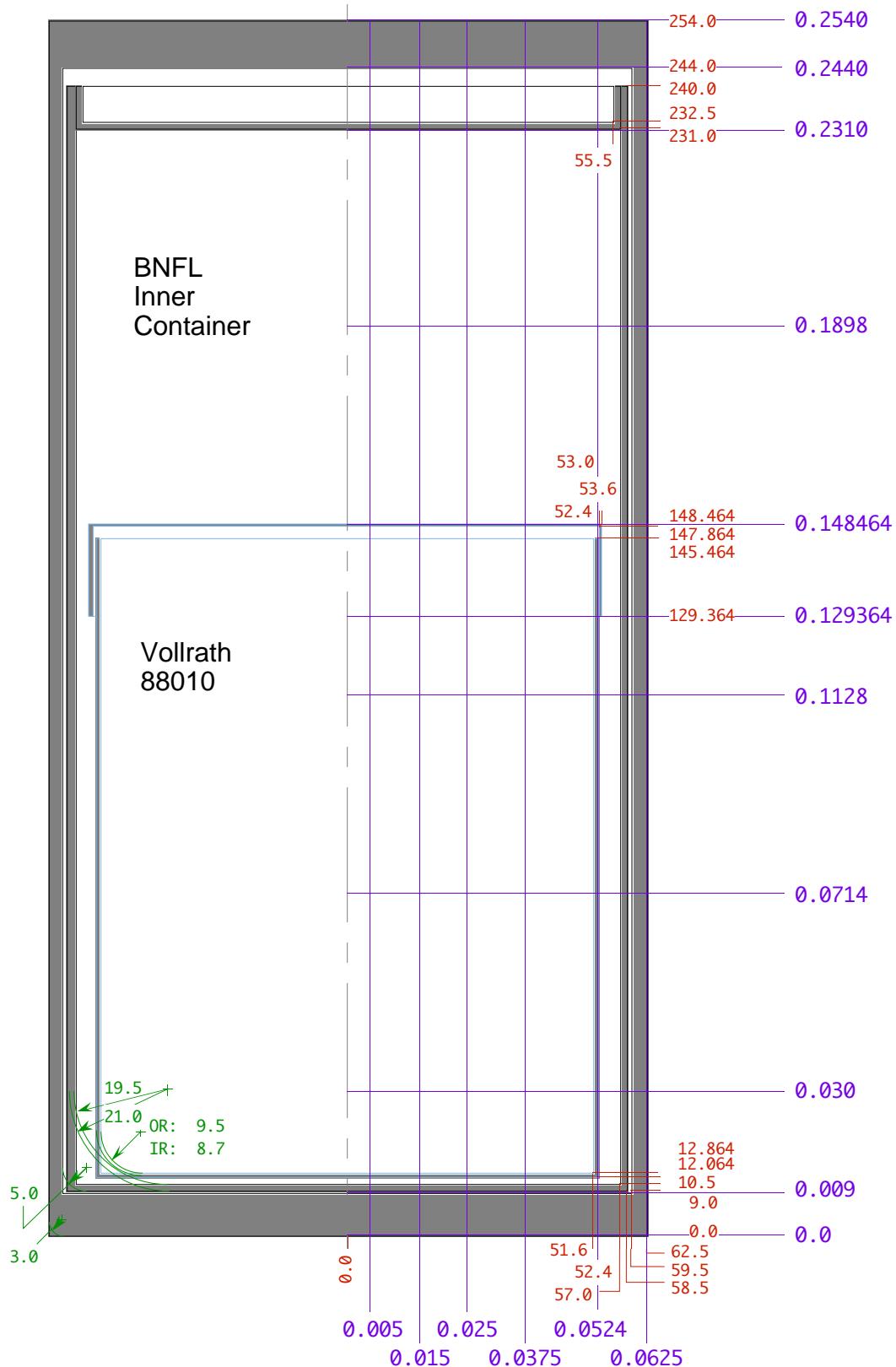


Fig. 2. Vollrath 88010 jar with the BNFL inner and outer containers.

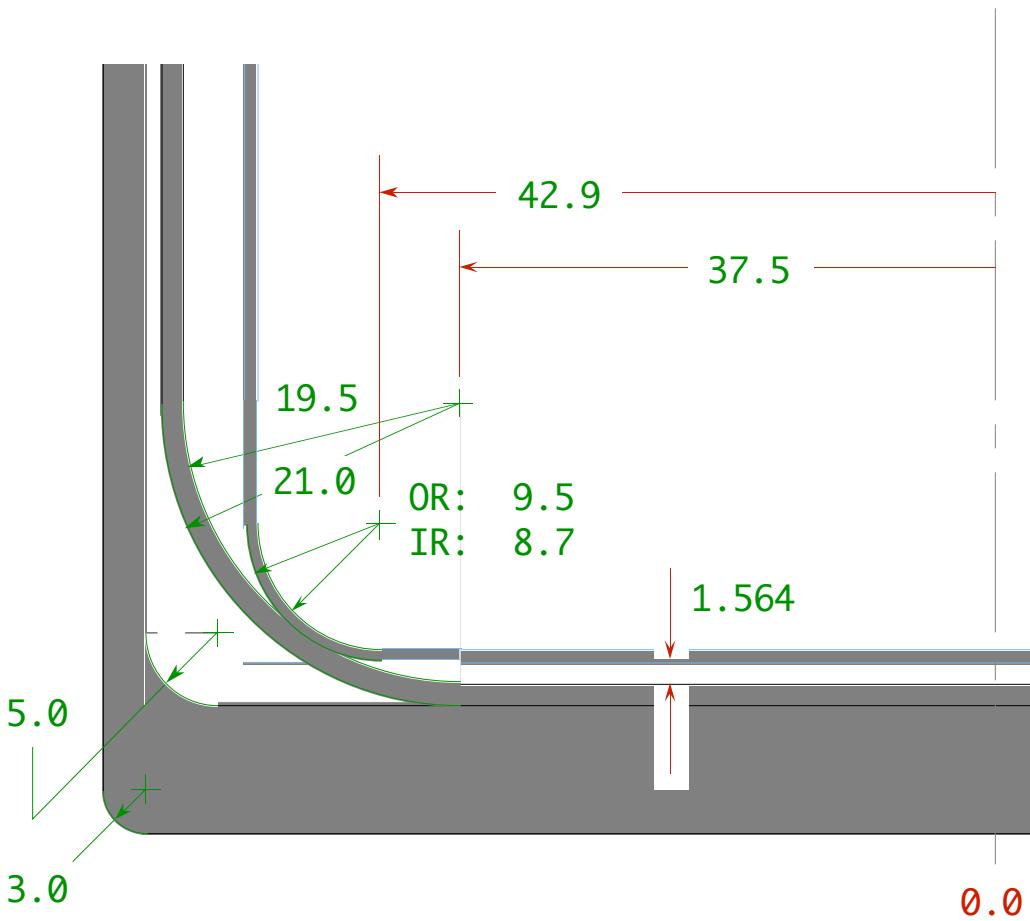


Fig. 3. Detail of the interference fit between the Vollrath jar and BNFL inner container.

The other configuration for plutonium metal consisted of two identical buttons. Each button was defined to be a spherical segment with one flat surface and one curved (spherical) surface. The dimensions of each button were set by a total mass per button

of 2.2 kg (4.85 lb<sub>m</sub>), a density of 19.86 g/cm<sup>3</sup> (1240 lb<sub>m</sub>/ft<sup>3</sup>), and a 0.0508-m (2.00-in.) radius for the spherical surface. The resulting dimensions for each button were a height of 0.0293 m (1.15 in.) and a diameter of 0.0921 m (3.62 in.). Figure 4 shows the BNFL-Vollrath container system with the two buttons. As with the ingot, the axes of the buttons coincides with the axes of the container assembly. The curved surfaces of the buttons are down to minimize the metal-to-metal contact area with the bottom of the Vollrath and between the two buttons. [These buttons would not fit through the mouth of the BNFL convenience jar. If the radius of the spherical surface were increased to 0.0666 m (2.62 in.), then the buttons would not fit into the Vollrath jar.]

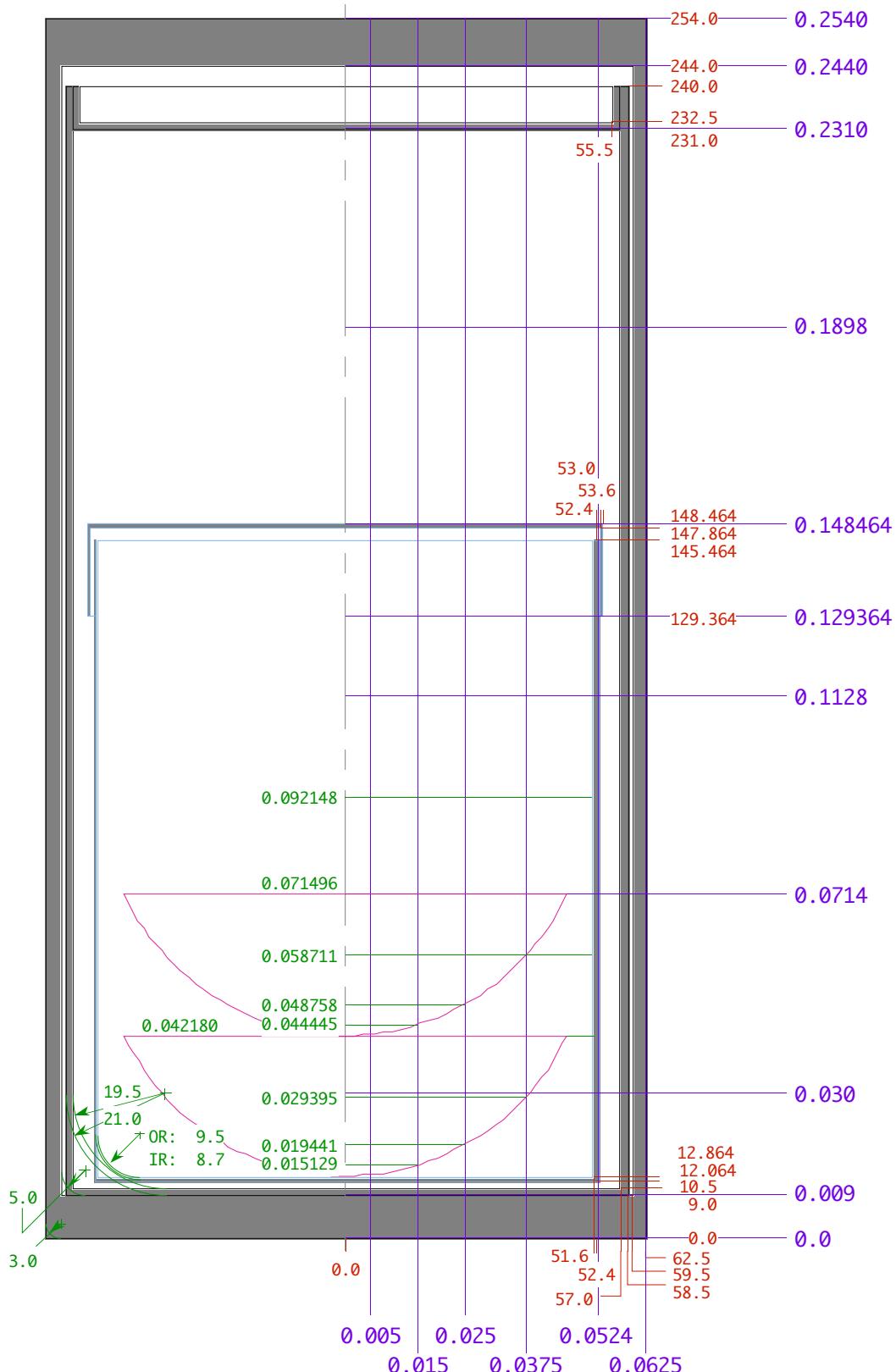


Fig. 4. Container assembly with two plutonium metal buttons.

As indicated in Section 3.0, the PuO<sub>2</sub> densities can range from 2.0 to ~6 g/cm<sup>3</sup> (125 to ~375 lb<sub>m</sub>/ft<sup>3</sup>). This range of densities is accommodated in the analyses by filling the BNFL convenience jar shown in Fig. 1 to the various levels in Table I. The levels shown in the table correspond to elevations in the figure and to boundaries between nodes in the model (note that zero elevation is below the bottom of the convenience jar).

## 6.0. ANALYSIS METHODOLOGY

We used the Thermal System Analysis Program<sup>11</sup> (TSAP) to calculate the temperature field throughout the stored material, containers, and external fixtures. The TSAP code solves the thermal-energy conservation equation on a volume- or surface-node basis. The nodal network describes the physical geometry of the system through volume and surface nodes and heat-transfer paths that connect the nodes. All three heat-transfer modes—conduction, convection, and radiation—can be represented in the code. Because TSAP lacks the required field equations to describe fluid motion, the representation of convection is necessarily through the definition of thermal resistances. Appendix B describes the nodal network methodology and the application of the TSAP code. It also describes the various correlations and curve fits used to define the material properties and heat-transfer coefficients required by the code.

Appendix B also provides node diagrams for the container assemblies with either an ingot or two buttons, as shown in Figs. 2 and 4, and for the container assembly with PuO<sub>2</sub> shown in Fig. 1. We initially analyzed the ingot because its geometry was simpler. Then we modified the model to represent the two buttons. Additional nodes and heat-transfer paths were added to describe the external fixtures defined by the four cases described in Section 3.0 (air, plate, drum, and cabinet). Appendices C and D contain listings of TSAP inputs for an ingot-and-drum case and for a buttons-and-cabinet case.

We generated a TSAP input model to describe storage of PuO<sub>2</sub> as shown in Fig. 1. Again, App. B provides a node diagram for this set of containers and product. A large uncertainty in the determination of the temperature field throughout the PuO<sub>2</sub> inside the BNFL convenience jar is the specification of the thermal conductivity of the PuO<sub>2</sub>

**TABLE I**  
**PuO<sub>2</sub> LEVELS, DENSITIES, AND MASSES IN THE BNFL CONVENIENCE JAR**

PuO <sub>2</sub> Level (m)	PuO <sub>2</sub> Density (g/cm <sup>3</sup> )	PuO <sub>2</sub> Mass (kg)
0.0921	6.70	4.99
0.1294	4.54	4.99
0.1898	3.02	4.99
0.2180	2.72	4.99
0.2180	2.00	3.67

powder. Appendix E is a listing of the input for 4.54 g/cm<sup>3</sup> oxide generating 3.01 W/kg. The external fixture in this deck is a plate.

We used a correlation by Deissler and Eian<sup>12</sup> to calculate the thermal conductivity of PuO<sub>2</sub> powder. This correlation describes the thermal conductivity of unconsolidated powders in terms of the porosity of the powder and the thermal conductivities of the solid material and the fill gas. Table II provides the resulting thermal conductivities for PuO<sub>2</sub> powders with three different fill gases. In our analyses, we only used the conductivities corresponding to air as the fill gas. The Hadley weighted-average correlation<sup>13</sup> also describes the thermal conductivity of powders, and it produces values somewhat higher than the Deissler-Eian correlation. Appendix B lists both correlations in detail.

References 12 and 14 make the point that if the average pore size in the powder is comparable to or smaller than the mean-free path of the gas molecules, then the thermal conductivity of the gas as applied in the correlation for thermal conductivity of powders should be reduced. Table III shows the average particle size at which this phenomenon begins to occur. The pressure at which the average pore size and mean-free path become comparable is described as the break-away pressure P<sub>b</sub> and

$$P_b \sim \frac{1}{D_p \cdot d^2} , \quad (1)$$

**TABLE II**  
**THERMAL CONDUCTIVITY OF PuO<sub>2</sub> POWDER**

<b>PuO<sub>2</sub> density</b>	<b>PuO<sub>2</sub> porosity</b>	<b>PuO<sub>2</sub> Thermal Conductivity</b>					
		<b>Fill Gas</b>					
		<b>helium</b>		<b>air</b>		<b>argon</b>	
<b>(g cm<sup>3</sup>)</b>	<b>(-)</b>	<b>(W m·K)</b>	<b>(Btu h·ft·°R)</b>	<b>(W m·K)</b>	<b>(Btu h·ft·°R)</b>	<b>(W m·K)</b>	<b>(Btu h·ft·°R)</b>
2.00	0.825	0.297	0.172	0.079	0.046	0.055	0.032
2.72	0.763	0.340	0.196	0.096	0.055	0.068	0.039
3.02	0.737	0.358	0.207	0.103	0.059	0.073	0.042
4.54	0.603	0.448	0.259	0.138	0.080	0.099	0.057
6.70	0.415	0.630	0.364	0.243	0.140	0.187	0.108

**TABLE III**  
**MINIMUM PuO<sub>2</sub> PARTICLE SIZES BASED ON THE BREAKAWAY PRESSURE**

<b>Fill gas</b>	<b>Minimum Particle Size</b>		
	<b>(mm)</b>	<b>(microns)</b>	<b>(in.)</b>
helium	0.612	612	0.0241
air	0.227	227	0.00896
argon	0.266	266	0.0105

where  $D_p$  is the average particle size and  $d$  is the mean gas-molecule diameter. Because helium has a much smaller mean molecular diameter than the other gases, Eq. (1) leads to the conclusion that average particle size at the breakaway pressure is much larger for helium than for the other gases. However, because helium has a much higher thermal conductivity than either air (or a nitrogen-rich mixture of nitrogen and oxygen) or argon, it still may be the best fill gas when storing oxide. More details can be found in App. B.

## 7.0. ANALYSIS RESULTS

We ran calculations for the three plutonium products defined in Section 5.0: a single metal ingot, a pair of metal buttons, and oxide. For the ingot and buttons, the calculations included the four external support structures defined in Section 3.0: the container assembly in air, the container assembly on a **plate**, the container assembly in a **drum**, and the container and drum assembly in a **cabinet**. In all cases the ultimate heat sink was through convection to 80°F (26.7°C) air and through radiation heat transfer to 80°F (26.7°C) stainless-steel walls. The base-case analyses assumed that the decay heat produced inside the plutonium product was 15 W or 3.41 W/kg, which is a little high for weapons-grade material (the maximum decay heat for weapons-grade plutonium is  $\leq$  3.0 W/kg). Sensitivity analyses investigated the following changes only for the case of two metal buttons in the container assembly on a plate:

- fill gas,
- decay heat,
- surface emissivities, and
- contact area between the inner and outer containers and between the outer container and the support plate.

The analyses of PuO<sub>2</sub> powders were limited to the plate case, the range of powder densities discussed in Section 5.0, and two specific powers, 3.006 and 6.012 W/kg oxide. The 3.006 W/kg corresponds to the generation of 15 W total in a container with 4.99 kg of oxide. At 6.012 W/kg, the same container would generate 30 W total, the maximum heat load allowed in the 3013 standard.

In the discussion of the results, heat transfer through metal-to-metal contact is referred to as conduction, and heat transfer from a metal surface to a gas is convection,

regardless of whether or not the convection is conduction limited. The number of digits used to display a calculated result does not imply the accuracy of the calculation but rather allows for comparison between calculations. The accuracy of the calculated temperatures, given reasonable uncertainty in the physical properties, is probably no better than to the nearest degree and may very well be several degrees. An assessment of the overall accuracy of the calculation requires comparisons to a prototypical database.

In the figures, zero elevation is always the bottom outside surface of the outer BNFL container; the 0.254-m (10-in.) elevation corresponds to the outside top surface of the outer BNFL container. Zero radius lies on the axis of symmetry in the containers described in Section 4.0, and the 0.0625-m (2.46-in.) radius is the outside cylindrical (or side) surface of the outer BNFL container. (Because the figures to be cited in this section include color, we have placed all of the figures for this section at the end of the section for convenience in assembling the report.)

### 7.1. Base-Case Results for the Plutonium-Metal Ingot and Buttons

The base-case analyses for plutonium metal included the following conditions:

Mass of plutonium:	4.4 kg (9.70 lb <sub>m</sub> )
Form of plutonium:	single ingot or pair of buttons
Fill gas:	helium
Decay heat:	15 W total (3.41 W/kg Pu or 1.55 W/lb <sub>m</sub> )
Emissivities:	0.5 for plutonium 0.3 for stainless steel

Table IV summarizes the calculated temperatures for the plutonium for the four cases defined in Section 3.0. The maximum plutonium temperature is the maximum calculated temperature from those nodes, both volume and surface, representing the plutonium. The maximum plutonium surface temperature is the maximum temperature from only the surface nodes for the plutonium. The average plutonium surface temperature is an area-average of the calculated plutonium surface temperatures. Figures 5 and 6 provide axial and radial temperature profiles from the four cases with the plutonium ingot, and Figs. 7 and 8 are similar plots for the plutonium buttons. The profiles are through the hot spot in the plutonium; for the button case, the radial profile is through the hot spot in the upper button, which is hotter than the lower button for the four cases.

One observation from Table IV is that the maximum temperature and the maximum surface temperature for the lower button are always the same. The reason is that the maximum temperature for the lower button occurs on the top surface just under the upper button (see Fig. 4). There is heat transfer from the upper button to the lower one, and this heat addition results in the surface temperature at this location on the lower button also being the maximum temperature for the button.

The air case required that all of the heat be removed from the outer container via convection and radiation heat transfer, which are relatively poor heat-transfer processes. For this case, the maximum temperature of the ingot is 193.9°F (89.9°C), and the upper- and lower-button maximum temperatures are 203.4 and 200.6°F (95.2 and

93.7°C), respectively. Even though the buttons together have almost 50% more surface area than the ingot, the button temperatures are 9.5 and 6.7°F (5.3 and 3.7°C) warmer than the ingot because the buttons lack the good conduction-heat-transfer path to the bottom of the Vollrath jar that exists for the ingot. [Note: We calculated temperature differences and units conversions with higher precision values than are shown in the text and tables.]

The plate case places the container on a 304 stainless steel plate. The plate provides a conduction path to remove heat from the bottom of the container and a larger area to convect and radiate heat to the heat sink. The net effect of the plate is better cooling for the container and the plutonium. As Table IV shows, the maximum plutonium temperatures are 16.6°F (9.2°C) lower for the ingot and 16.5°F (9.2°C) lower for the upper button than in the air case. The differences between the button and ingot maximum temperatures are approximately the same as those for the air case.

The drum case for the container also provides a conduction path to remove heat from the container, but it also adds walls that act as barriers to heat transfer. The effect of the barriers is that convection and radiation heat transfer to the heat sinks occur in multiple steps, which reduces the effectiveness of the heat-transfer processes. The net result is that the maximum plutonium temperatures in the drum are only slightly lower than the air case.

The cabinet case appears in Table IV as two subcases, labeled cabinet case and no-flow cabinet. The cabinet design<sup>8</sup> indicates that because of the overlaps between adjacent cabinets, the shelves are totally enclosed by solid surfaces with the exception of small gaps at the bottom and top of the cabinet and around the edges of shelves. It is not clear if these gaps are sufficient to allow significant natural circulation flows. If these flows exist, they are driven by buoyancy forces resulting from temperature differences, and hence density differences, between the air inside the cabinet and the air outside the cabinet. Quantification of these natural circulation flows was outside the scope of the current analysis effort and beyond the capabilities of the TSAP code. Therefore, we made an assumption that the magnitude of the natural circulation flow is sufficient to maintain the air inside the cabinet at 5°F (2.8°C) above the outside air, and the cabinet case includes this assumption by setting the air nodes inside the cabinet to 85°F (29.4°C). The no-flow cabinet case assumes that the natural circulation flow does not exist, and that the temperature of the air inside the cabinet is determined completely by the heat-transfer processes modeled by TSAP.

**TABLE IV**  
**PLUTONIUM METAL TEMPERATURES**

	Maximum Pu temperature	Maximum Pu surface temperature	Average Pu surface temperature
<b>Plutonium ingot (15 W)</b>			
Air case	193.9°F (89.9°C)	192.4°F (89.1°C)	187.1°F (86.2°C)
Plate case	177.2°F (80.7°C)	175.8°F (79.9°C)	168.9°F (76.0°C)
Drum case	191.9°F (88.8°C)	190.5°F (88.1°C)	182.9°F (83.8°C)
Cabinet case	204.8°F (96.0°C)	203.5°F (95.3°C)	196.2°F (91.2°C)
No-flow cabinet	225.2°F (107.4°C)	224.0°F (106.6°C)	217.0°F (102.8°C)
<b>Plutonium buttons (15 W)</b>			
<b>Upper button (7.5 W)</b>			
Air case	203.4°F (95.2°C)	202.9°F (94.9°C)	200.8°F (93.8°C)
Plate case	186.9°F (86.0°C)	186.1°F (85.6°C)	184.5°F (84.7°C)
Drum case	201.9°F (94.4°C)	201.2°F (94.0°C)	199.7°F (93.1°C)
Cabinet case	214.7°F (101.5°C)	214.1°F (101.1°C)	212.5°F (100.3°C)
No-flow cabinet	234.9°F (112.7°C)	234.3°F (112.4°C)	232.8°F (111.6°C)
<b>Lower button (7.5 W)</b>			
Air case	200.6°F (93.7°C)	200.6°F (93.7°C)	196.2°F (91.2°C)
Plate case	182.5°F (83.6°C)	182.5°F (83.6°C)	176.8°F (80.5°C)
Drum case	196.6°F (91.4°C)	196.6°F (91.4°C)	190.5°F (88.0°C)
Cabinet case	209.7°F (98.7°C)	209.7°F (98.7°C)	203.8°F (95.5°C)
No-flow cabinet	230.1°F (110.1°C)	230.1°F (110.1°C)	224.4°F (106.9°C)

Figure 5 and Table IV show the effect of fixing the air temperature inside the cabinet for the cabinet case. Fixing the air temperature results in most of the heat from the container being rejected to the air inside the cabinet; only 3.3 W (22% of the decay heat) is rejected from the cabinet door outside surface. The cabinet door is coupled to the rest of the cabinet structure by conduction and radiation paths. At the elevation shown in Fig. 5, the door is warmer than the air inside the cabinet. It therefore rejects heat by convection to the air inside the cabinet and by convection and radiation to the heat-sinks outside the cabinet. The assumption of natural circulation mitigates the adverse effect of added heat-transfer barriers introduced by the cabinet, and the maximum plutonium temperatures are only ~10°F (5.6°C) warmer than those for the air case. The peak plutonium temperatures are now in the range 205–215°F (96–102°C).

By contrast, the no-flow cabinet forces all of the decay heat to be rejected from the outside surface of the door, and the maximum plutonium temperatures are ~20°F (11.1°C) higher than the cabinet case and ~30°F (16.7°C) higher than the air case. The peak temperatures increase to the range of 225–235°F (107–113°C). Because all of the heat from inside the cabinet is rejected only from the cabinet door as a result of the symmetry assumptions in the TSAP model, the no-flow cabinet tends to represent a

worst case for the storage system. The symmetry assumptions of the model require that the cabinet and all of its neighbors be fully loaded (each storage position in the cabinets generates 15 W), ignore the possibility of flows inside or between the cabinets, and ignore heat transfer to the floor and from the top of the cabinet.

Figures 5–8 begin to indicate that the outer BNFL container may also be fairly warm. Table V shows the maximum-surface and surface-average temperatures for the outer container for both metal forms and all cases of external support structures. The maximum temperatures are 133–170°F (56–77°C). For the ingot, the maximum temperature on the outer container occurs on the bottom surface for the air and plate cases and on the side surface for the drum and cabinet cases. For the buttons, the maximum occurs on the container bottom surface for the air case and on the side surface for other cases. The container temperatures are very similar between the ingot and button forms for each case.

Tables VI and VII show the distribution of heat transfer from the plutonium metal among the surfaces of the metal and among the heat-transfer modes. The overall category for the buttons is effectively an averaging of the two buttons. The definition of surfaces is obvious for the ingot but not so for the buttons. For purposes of Table VI, we have defined the bottom of each button as extending to a radius of 5 mm (0.20 in.) on the lower surface; this definition corresponds to the inner-most radial node from Fig. 4. Heat transfer from the bottom of each button is by convection to a very thin gas layer and by radiation to the solid surface on the other side of the gas layer. The convection process on the bottom surface of the button is conduction limited, but by our definition it is still convection. The remainder of the lower surface of the button is defined as the side of the button. The top of the button is the flat upper surface.

**TABLE V**  
**BNFL OUTER CONTAINER SURFACE TEMPERATURES**

	Maximum container surface temperature	Average container surface temperature
<b>Plutonium ingot (15 W)</b>		
Air case	144.8°F (62.7°C)	119.4°F (48.5°C)
Plate case	116.0°F (46.7°C)	107.5°F (41.9°C)
Drum case	133.3°F (56.3°C)	126.1°F (52.3°C)
Cabinet case	146.6°F (63.7°C)	139.1°F (59.5°C)
No-flow cabinet	168.2°F (75.7°C)	160.6°F (71.5°C)
<b>Plutonium buttons (15 W)</b>		
Air case	144.5°F (62.5°C)	119.3°F (48.5°C)
Plate case	117.1°F (47.3°C)	107.5°F (41.9°C)
Drum case	134.3°F (56.8°C)	126.3°F (52.4°C)
Cabinet case	148.1°F (64.5°C)	139.3°F (59.6°C)
No-flow cabinet	169.8°F (76.6°C)	160.8°F (71.6°C)

**TABLE VI**  
**HEAT-TRANSFER DISTRIBUTION FROM THE PLUTONIUM METAL**  
**BY SURFACE**

	Fraction of heat transfer from bottom of Pu	Fraction of heat transfer from side of Pu	Fraction of heat transfer from top of Pu
<b>Plutonium ingot (15 W)</b>			
Air case	0.3057	0.6428	0.0515
Plate case	0.3514	0.6019	0.0467
Drum case	0.3779	0.5789	0.0432
Cabinet case	0.3719	0.5845	0.0436
No-flow cabinet	0.3686	0.5880	0.0434
<b>Plutonium buttons (15 W)</b>			
<b>Upper button (7.5 W)</b>			
Air case	0.0130	0.5733	0.4137
Plate case	0.0194	0.5999	0.3807
Drum case	0.0233	0.6136	0.3631
Cabinet case	0.0226	0.6095	0.3679
No-flow cabinet	0.0224	0.6071	0.3705
<b>Lower button (7.5 W)</b>			
Air case	0.0593	0.8453	0.0954
Plate case	0.0683	0.8855	0.0462
Drum case	0.0731	0.9113	0.0156
Cabinet case	0.0716	0.9077	0.0207
No-flow cabinet	0.0704	0.9079	0.0217
<b>Overall</b>			
Air case	0.0361	0.7093	0.2546
Plate case	0.0439	0.7427	0.2134
Drum case	0.0482	0.7625	0.1893
Cabinet case	0.0471	0.7586	0.1943
No-flow cabinet	0.0464	0.7575	0.1961

**TABLE VII**  
**HEAT-TRANSFER DISTRIBUTION FROM THE PLUTONIUM METAL**  
**BY HEAT-TRANSFER MODE**

	Fraction of heat transfer from Pu by conduction	Fraction of heat transfer from Pu by convection	Fraction of heat transfer from Pu by radiation
<b>Plutonium ingot (15 W)</b>			
Air case	0.3057	0.6162	0.0781
Plate case	0.3514	0.5798	0.0688
Drum case	0.3779	0.5524	0.0697
Cabinet case	0.3719	0.5544	0.0737
No-flow cabinet	0.3686	0.5519	0.0795
<b>Plutonium buttons (15 W)</b>			
<b>Upper button (7.5 W)</b>			
Air case	0.0	0.8787	0.1213
Plate case	0.0	0.8883	0.1117
Drum case	0.0	0.8834	0.1166
Cabinet case	0.0	0.8776	0.1224
No-flow cabinet	0.0	0.8687	0.1313
<b>Lower button (7.5 W)</b>			
Air case	0.0	0.9209	0.0791
Plate case	0.0	0.9282	0.0718
Drum case	0.0	0.9257	0.0743
Cabinet case	0.0	0.9218	0.0782
No-flow cabinet	0.0	0.9158	0.0842
<b>Overall</b>			
Air case	0.0	0.8998	0.1002
Plate case	0.0	0.9082	0.0918
Drum case	0.0	0.9046	0.0954
Cabinet case	0.0	0.8997	0.1003
No-flow cabinet	0.0	0.8923	0.1077

Table VI shows that the external support structures represented by the various cases have only a minimal effect on the distribution by surface of heat transfer away from the ingot and the buttons. The main effect of the external structures is the addition of a conduction path away from the bottom of the container assembly relative to the air case, and it shows up as small increases in the heat transfer out the bottoms of both the ingot and the buttons.

Table VII indicates that 30–37% of the decay heat in the ingot is removed by conduction, which we have defined as metal-to-metal contact. Convection, which we have defined as heat transfer from a solid surface to a gas, removes 55–62% of the heat from the ingot, and radiation accounts for 7–8%. By contrast, the buttons have no conduction heat transfer because there is no metal-to-metal contact at the surface of the buttons (the model assumes that the contact on the curved lower surfaces is vanishingly small).

Convection heat transfer accounts for 87–89% of the heat removal from the upper button and 92–93% of the heat removal from the lower button. The difference between the two buttons is related to the impact of radiation heat transfer and the fact that the upper button rejects some heat to the lower button. The upper surface of the lower button is mostly blanketed by the hotter upper button, and net radiation exchange is from the upper to the lower button. The top surface of the upper button is able to radiate to the cooler surfaces of the Vollrath jar.

Tables VI and VII reveal significant differences in the heat-transfer distribution between the ingot and the buttons. The ingot rejects more heat through its bottom surface than the buttons, and because the bottom of the ingot is coupled to the bottom of the Vollrath jar through a conduction path (with a contact resistance), this fraction of the heat generated by the ingot is rejected with a relatively small temperature difference. Therefore, for a given case, the ingot is cooler than either button in spite of the buttons having more total surface area. The buttons are cooled primarily by convection, which results in higher thermal resistances than conduction through metal, and hence require larger temperature differences.

Tables VIII and IX distribute the heat transfer from the outside surface of the BNFL outer container among the surfaces and among the heat-transfer modes. Through our definitions, conduction heat transfer can occur only through metal-to-metal contact when the container is placed on a steel surface. Heat transfer from the container bottom surface is by convection for the air case and by conduction for the other cases. The side and top surfaces of the container can only reject heat by convection and radiation because there is no metal-to-metal contact.

Radiation heat transfer accounts for 12–22% of the heat removal from the outside of the container assembly and significantly impacts cooling of the container and the temperature of the plutonium. The 12% contribution comes from the plate case and is misleading. For this case, the radiation contribution dropped because the large increase in conduction heat transfer to the plate cooled the container and reduced the potential for radiation heat transfer.

The change from the air case to the plate case is the addition of a conduction path from the bottom of the container to a plate. This change results in a significant increase in the heat transfer from the bottom surface of the container. A further consequence of the change is that the plutonium temperatures drop significantly, as shown in Table IV. However, the transition from the plate to the drum also increased conduction from the bottom of the container, but for this change, the plutonium temperatures increased. As explained previously, the effect is the result of the drum introducing solid walls that reduce convection and radiation from the side walls and top of the container and from the top surface of the bottom of the drum, which is now effectively the plate in the previous case. The overall effect of the drum is to insulate the container and increase its temperature, which increases the temperature differences driving conduction.

As explained in Section 4.0, there is an interference between the Vollrath jar and the BNFL inner container that results in a 1.56-mm (0.061-in.) gap between the two bottoms. Table X shows the impact of closing that gap on the plutonium temperatures. The net effect of closing the gap is to reduce the maximum temperature in the ingot by 7.3 and

**TABLE VIII**  
**HEAT-TRANSFER DISTRIBUTION FROM THE OUTSIDE OF THE BNFL OUTER**  
**CONTAINER BY SURFACE**

	Fraction of heat transfer from outer container bottom	Fraction of heat transfer from outer container side	Fraction of heat transfer from outer container top
<b>Plutonium ingot (15 W)</b>			
Air case	0.1089	0.8377	0.0534
Plate case	0.4106	0.5491	0.0403
Drum case	0.6146	0.3253	0.0601
Cabinet case	0.5839	0.3509	0.0652
No-flow cabinet	0.5766	0.3567	0.0667
<b>Plutonium buttons (15 W)</b>			
Air case	0.1107	0.8389	0.0504
Plate case	0.4102	0.5516	0.0382
Drum case	0.6108	0.3303	0.0589
Cabinet case	0.5810	0.3552	0.0638
No-flow cabinet	0.5741	0.3606	0.0653

**TABLE IX**  
**HEAT-TRANSFER DISTRIBUTION FROM THE OUTSIDE OF THE BNFL OUTER**  
**CONTAINER BY HEAT-TRANSFER MODE**

	Fraction of heat transfer from outer container by conduction	Fraction of heat transfer from outer container by convection	Fraction of heat transfer from outer container by radiation
<b>Plutonium ingot (15 W)</b>			
Air case	0.0	0.7793	0.2207
Plate case	0.4106	0.4685	0.1209
Drum case	0.6146	0.2381	0.1473
Cabinet case	0.5839	0.2512	0.1649
No-flow cabinet	0.5766	0.2428	0.1806
<b>Plutonium buttons (15 W)</b>			
Air case	0.0	0.7792	0.2208
Plate case	0.4102	0.4689	0.1209
Drum case	0.6108	0.2405	0.1487
Cabinet case	0.5810	0.2529	0.1661
No-flow cabinet	0.5741	0.2441	0.1818

**TABLE X**  
**EFFECT OF CLOSING THE GAP BETWEEN THE BOTTOMS OF THE VOLLRATH JAR AND THE BNFL INNER CONTAINER**

	Maximum Pu $\Delta T$	Maximum Pu surface $\Delta T$	Average Pu surface $\Delta T$
<b>Plutonium ingot (15 W)</b>			
Air case	-7.3°F (-4.1°C)	-7.2°F (-4.0°C)	-9.5°F (-5.3°C)
Plate case	-10.8°F (-6.0°C)	-10.4°F (-5.8°C)	-13.7°F (-7.6°C)
<b>Plutonium buttons (15 W)</b>			
<b>Upper button (7.5 W)</b>			
Air case	-3.9°F (-2.2°C)	-4.1°F (-2.3°C)	-3.7°F (-2.0°C)
Plate case	-5.6°F (-3.1°C)	-5.5°F (-3.0°C)	-5.4°F (-3.0°C)
<b>Lower button (7.5 W)</b>			
Air case	-5.4°F (-3.0°C)	-5.4°F (-3.0°C)	-6.2°F (-3.4°C)
Plate case	-7.6°F (-4.2°C)	-7.6°F (-4.2°C)	-8.6°F (-4.8°C)

10.8°F (4.1 and 6.0°C) for the air and plate cases, respectively. The plate case has a bigger effect because the addition of the plate enhances heat removal from the bottom of the container. For the buttons, the maximum temperature, which occurs in the upper button, is reduced by 3.9 and 5.6°F (2.2 and 3.1°C) for the same two cases. The effect in the buttons is smaller because the buttons, particularly the upper button, are not as tightly coupled to the bottom of the container as the ingot. The temperature differences across the gap (gap  $\Delta T$ ) for the ingot in the base-case analyses are 26.0°F (14.5°C) for the air case and 31.2°F (17.3°C) for the plate case. For the buttons, the temperature differences are 21.8°F (12.1°C) and 26.3°F (14.6°C). Closing the gap reduced the temperature differences in all cases to essentially zero. The plutonium did not experience decreases of the same magnitude because the gap  $\Delta T$  gets split between the BNFL side and the Vollrath side of the gap (the BNFL side gets hotter and the Vollrath side gets cooler), and then a subtle rebalancing of the heat-transfer mechanisms and the temperature distributions further mitigate the effect on the plutonium temperatures.

## 7.2. Sensitivity Results for Plutonium-Metal Buttons and the Plate Case

We ran the sensitivity variations on the case with the plutonium in the form of two buttons and the container assembly on a plate. We selected the two buttons instead of the ingot because the buttons were hotter and because ingot is less common. Because the sensitivity changes involved only parameters inside the container, we selected the plate case as relatively simple and realistic without the thermal barriers introduced by the drum and cabinet. The base-case conditions for the container assembly were a fill gas of helium, 15-W total power, and emissivities of the plutonium and stainless steel of 0.5 and 0.3, respectively. Figure 4 shows the container design and configuration of the buttons.

Table XI presents the results for all of the sensitivity cases in the form of temperature changes ( $\Delta T$ ) relative to the base case presented in Section 7.1, where

$$\Delta T = T_{\text{sensitivity case}} - T_{\text{base case}} . \quad (2)$$

If the  $\Delta T$  from the table is positive, the change case produced a temperature higher than the base case. The descriptions of the sensitivity cases shown in the table reflect the total change from the base case; there are no multiple changes unless the description in the table includes multiple changes. In the base case, the upper button was slightly hotter than the lower button, and the effects of the sensitivity changes are generally slightly larger in magnitude for the upper button than the lower.

The first series of sensitivity cases changes the fill gas from helium to air or argon. At 212°F (100°C), the thermal conductivity of air is only 15.7% of that for helium, and the thermal conductivity of argon is even lower, i.e., 12.2% of helium. The sensitivity results produced peak plutonium temperatures that are 137.6°F (76.4°C) higher for air than the base case and 165.8°F (92.1°C) higher for argon. We used air in the calculation to approximate any nitrogen-rich gas mixture.

The next series of sensitivity changes increase the decay heat from the 15 W in the base case to 20, 25, and 30 W. Clearly, as the decay heat increases, so do the plutonium temperatures. An interesting observation is that increasing the decay heat to 30 W, the maximum allowed in the 3013 standard, still results in temperatures lower than that produced by the air and argon sensitivity cases.

Next, we vary the surface emissivities for the plutonium and stainless steel. The original estimate of 0.5 for the plutonium emissivity ( $\epsilon_{Pu}$ ) is subject to quite a bit of uncertainty. The  $\epsilon_{Pu}$  certainly depends on the surface finish, with an oxidized surface having a higher value and a clean, shiny surface having a lower value. We increase  $\epsilon_{Pu}$  to 0.8 and decrease it to 0.3. References for the emissivity of stainless steel ( $\epsilon_{SS}$ ) do not distinguish between 316 and 304 stainless steel. The original estimate for  $\epsilon_{SS}$  is 0.3, which is typical of commercially available stainless steel without special surface treatments. We increase  $\epsilon_{SS}$  to 0.6, which is typical for an oxidized surface, and decrease it to 0.2, which is typical for a polished surface; more aggressive surface treatments for stainless steel can produce even higher or lower values. We also ran the case in which we set both  $\epsilon_{Pu}$  and  $\epsilon_{SS}$  to zero, effectively turning off the radiation heat transfer and showing the total temperature effect associated with that heat-transfer mode.

The results summarized in Table XI show that the changes in the  $\epsilon_{SS}$  produced bigger effects on the plutonium temperatures than did the changes in  $\epsilon_{Pu}$ . The reason for the greater sensitivity to  $\epsilon_{SS}$  is that there are more stainless steel surfaces, with larger areas, associated with the containers. The  $\epsilon_{Pu}$  affects only the radiation to the inside of the Vollrath jar, but the  $\epsilon_{SS}$  affects not only the radiation to the inside of the Vollrath but also between each pair of containers and from the outside of the container. The best case, with  $\epsilon_{Pu}$  of 0.8 and  $\epsilon_{SS}$  of 0.6, lowers the maximum plutonium temperature by 11.1°F (6.2°C), and the worst case with  $\epsilon_{Pu}$  of 0.3 and  $\epsilon_{SS}$  of 0.2 increases the maximum temperature by 4.0°F (2.2°C). Turning off radiation heat transfer produces an increase of 11.3°F (6.3°C) over the base case.

**TABLE XI**  
**PLUTONIUM METAL TEMPERATURE CHANGES FOR THE SENSITIVITY  
CASES**

	Maximum Pu $\Delta T$	Maximum Pu surface $\Delta T$	Average Pu surface $\Delta T$
<b>Plutonium buttons: plate case</b>			
<b>Upper button</b>			
<b>Change cases</b>			
Fill Gas			
Air	137.6°F (76.4°C)	138.1°F (76.7°C)	137.7°F (76.5°C)
Argon	165.8°F (92.1°C)	166.4°F (92.4°C)	166.0°F (92.2°C)
Decay heat			
20 W total <sup>a</sup>	31.5°F (17.5°C)	31.4°F (17.4°C)	30.9°F (17.2°C)
25 W total <sup>a</sup>	61.8°F (34.3°C)	61.4°F (34.1°C)	60.5°F (33.6°C)
30 W total <sup>a</sup>	90.9°F (50.5°C)	90.4°F (50.2°C)	89.0°F (49.5°C)
Emissivities			
$\epsilon_{Pu}=0.3$ (decrease)	1.3°F (0.7°C)	1.3°F (0.7°C)	1.4°F (0.8°C)
$\epsilon_{SS}=0.2$ (decrease)	3.2°F (1.8°C)	3.3°F (1.8°C)	3.3°F (1.8°C)
$\epsilon_{Pu}=0.3, \epsilon_{SS}=0.2$	4.0°F (2.2°C)	4.1°F (2.3°C)	4.1°F (2.3°C)
$\epsilon_{Pu}=0.8$ (increase)	-1.2°F (-0.7°C)	-1.2°F (-0.7°C)	-1.2°F (-0.7°C)
$\epsilon_{SS}=0.6$ (increase)	-8.3°F (-4.6°C)	-8.3°F (-4.6°C)	-8.4°F (-4.7°C)
$\epsilon_{Pu}=0.8, \epsilon_{SS}=0.6$	-11.1°F (-6.2°C)	-11.1°F (-6.2°C)	-11.3°F (-6.3°C)
no radiation	11.3°F (6.3°C)	11.5°F (6.4°C)	11.5°F (6.4°C)
Contact areas—			
add gaps between			
In./out. BNFL <sup>b</sup>	0.7°F (0.4°C)	0.7°F (0.4°C)	0.6°F (0.4°C)
and BNFL/plate <sup>c</sup>	2.4°F (1.3°C)	2.4°F (1.3°C)	2.3°F (1.3°C)
<b>Lower button</b>			
<b>Change cases</b>			
Fill Gas			
Air	132.8°F (73.8°C)	132.8°F (73.8°C)	134.8°F (74.9°C)
Argon	160.9°F (89.4°C)	160.9°F (89.4°C)	163.6°F (90.9°C)
Decay heat			
20 W total <sup>a</sup>	30.4°F (16.9°C)	30.4°F (16.9°C)	28.9°F (16.1°C)
25 W total <sup>a</sup>	59.6°F (33.1°C)	59.6°F (33.1°C)	56.8°F (31.6°C)
30 W total <sup>a</sup>	87.7°F (48.7°C)	87.7°F (48.7°C)	83.7°F (46.5°C)
Emissivities			
$\epsilon_{Pu}=0.3$ (decrease)	1.1°F (0.6°C)	1.1°F (0.6°C)	1.0°F (0.5°C)
$\epsilon_{SS}=0.2$ (decrease)	3.1°F (1.7°C)	3.1°F (1.7°C)	3.0°F (1.6°C)

**TABLE XI (cont)**  
**PLUTONIUM METAL TEMPERATURE CHANGES FOR THE SENSITIVITY**  
**CASES**

Emissivities					
$\epsilon_{Pu}=0.3, \epsilon_{SS}=0.2$	3.7°F (2.1°C)	3.7°F (2.1°C)	3.5°F (1.9°C)		
$\epsilon_{Pu}=0.8$ (increase)	-0.9°F (-0.5°C)	-0.9°F (-0.5°C)	-0.7°F (-0.4°C)		
$\epsilon_{SS}=0.6$ (increase)	-7.9°F (-4.4°C)	-7.9°F (-4.4°C)	-7.7°F (-4.3°C)		
$\epsilon_{Pu}=0.8, \epsilon_{SS}=0.6$	-10.4°F (-5.8°C)	-10.4°F (-5.8°C)	-9.9°F (-5.5°C)		
no radiation	10.4°F (5.8°C)	10.4°F (5.8°C)	9.8°F (5.5°C)		
Contact areas—					
add gaps between					
In./out. BNFL <sup>b</sup>	0.9°F (0.5°C)	0.9°F (0.5°C)	1.0°F (0.6°C)		
and BNFL/plate <sup>c</sup>	2.9°F (1.6°C)	2.9°F (1.6°C)	3.2°F (1.8°C)		

<sup>a</sup> Total power is the combined power of both buttons. Each button has one half of the total power.

<sup>b</sup> This gap is a 1-mm-thick helium gap that spans a 0.0–0.025-m radius between the bottoms of the inner and outer BNFL containers (see Fig. 1).

<sup>c</sup> This case includes the gap in footnote b above and a 1-mm air gap between the bottom of the outer BNFL container and the plate that spans 0.0–0.0524-m radius.

The final two sensitivity changes involve adding a gap to decrease the contact area between the BNFL inner and outer containers and then adding a similar gap between the BNFL outer container and the plate. In the table, the first case is a single gap added to the original container design, and the second case includes two gaps. The intent of these two sensitivity cases is to look at the effect of design changes in the containers that might compensate for irregularities in the bottom surfaces of the containers or in the plate. However, if the manufacturing tolerances are lax for producing the flat surfaces of the containers (or the surface on which the container sits) or if warping occurs over time because of temperature and pressure effects, the contact areas could be much smaller than those represented in the change cases.

The gap between the bottoms of the BNFL inner and outer containers was 1 mm (0.04 in.) thick and extends from the axis to a radius of 0.025 m (0.98 in.) (see Fig. 4). This gap restricts the contact between the two containers to the area between 0.025- to 0.0375-m (0.98- to 1.48-in.) radius. The design of the inner container prevents contact at a larger radius. The gap between the inner and outer containers, which reduces the contact area by 44%, is filled with the normal fill gas, which in this case is helium. The gap between the outer container and the plate, also 1 mm (0.04 in.) thick, extends to a radius of 0.0524 m (2.06 in.) and reduces the contact area with the plate by 78%. Air fills this gap. As Table XI shows, the changes in plutonium maximum temperature are

relatively small—0.7°F (0.4°C) for only the gap between the inner and outer container and 2.4°F (1.3°C) for both gaps.

### 7.3. Results for Plutonium Oxide

The analyses with PuO<sub>2</sub> uses the container assembly shown in Fig. 1. We consider five different densities spanning the range 2.00–6.70 g/cm<sup>3</sup> (125–418 lb<sub>m</sub>/ft<sup>3</sup>) at two specific powers, 3.006 and 6.012 W/kg (1.363 and 2.727 W/lb<sub>m</sub>). Previously, Table I had shown the levels to which the various oxides filled the BNFL convenience jar. Table XII shows the mass and total decay heat for the oxide as a function of density. Because the 2.00-g/cm<sup>3</sup> (125-lb<sub>m</sub>/ft<sup>3</sup>) oxide fills the convenience jar before the mass limit is reached, it is necessary to compare results from different densities on the basis of specific power instead of total power.

Figures 9 and 10 give the axial and radial temperature profiles for the various oxides at a specific power of 3.006 W/kg (1.363 W/lb<sub>m</sub>). Figure 10 shows the radial profile at the elevation corresponding to the maximum temperature. Table XII shows the elevations of the maximum temperature ( $T_{\text{maximum}}$ ), which are the same for both specific powers. In the table and in the figure, zero elevation corresponds to the bottom outside surface of the outer container. Figures 11 and 12 give the corresponding profiles for a specific power of 6.012 W/kg (2.727 W/lb<sub>m</sub>).

Table XIII summarizes the temperature results for all of the oxide analyses. The average temperature is a volume average. The minimum temperature occurs at the bottom outermost oxide node for all cases. The peak temperatures were 250.8°F (121.6°C) at a specific power of 3.006 W/kg (1.363 W/lb<sub>m</sub>) and 414.1°F (212.3°C) at a specific power of 6.012 W/kg (2.727 W/lb<sub>m</sub>), both for an oxide density of 4.54 g/cm<sup>3</sup> (283 lb<sub>m</sub>/ft<sup>3</sup>). Except for the lowest and highest densities, the peak temperatures do not vary much with density. The 2.00-g/cm<sup>3</sup> (125-lb<sub>m</sub>/ft<sup>3</sup>) oxide has a significantly lower temperature because the total power is reduced. The 6.70-g/cm<sup>3</sup> (418-lb<sub>m</sub>/ft<sup>3</sup>) oxide has a lower temperature because it has a substantially higher thermal conductivity [76% greater than the 4.54-g/cm<sup>3</sup> (283-lb<sub>m</sub>/ft<sup>3</sup>) oxide] and a lower overall height of the oxide. Figure 13 also shows the peak temperatures as a function of density.

Table XIV shows the maximum and average temperatures for the outside surface of the BNFL outer container. Compared with the results for the metal ingot and buttons, the peak container temperatures are slightly cooler, but the average temperature is slightly higher. Variations in how the heat is moved from the product to the surface of the outer container explain the differences.

**TABLE XII**  
**PuO<sub>2</sub> DENSITIES, MASSES, AND TOTAL POWER**

PuO <sub>2</sub> Density (g/cm <sup>3</sup> )	PuO <sub>2</sub> Mass (kg)	Total Power (W) (3.006 W/kg)	Total Power (W) (6.012 W/kg)	Elevation of $T_{\text{maximum}}$
2.00	3.67	11.032	22.065	121.1 mm (4.77 in.)
2.72	4.99	15.000	30.000	121.1 mm (4.77 in.)
3.02	4.99	15.000	30.000	102.5 mm (4.03 in.)
4.54	4.99	15.000	30.000	81.8 mm (3.22 in.)
6.70	4.99	15.000	30.000	61.1 mm (2.40 in.)

**TABLE XIII**  
**PuO<sub>2</sub> TEMPERATURES**

	Maximum PuO <sub>2</sub> temperature	Average PuO <sub>2</sub> temperature	Minimum PuO <sub>2</sub> temperature
<b>3.006 W/kg oxide</b>			
2.00 g/cm <sup>3</sup> oxide	217.9°F (103.3°C)	162.6°F (72.5°C)	125.3°F (51.9°C)
2.72 g/cm <sup>3</sup> oxide	243.2°F (117.4°C)	180.5°F (82.5°C)	136.9°F (58.3°C)
3.02 g/cm <sup>3</sup> oxide	246.7°F (119.3°C)	183.7°F (84.3°C)	139.3°F (59.6°C)
4.54 g/cm <sup>3</sup> oxide	250.8°F (121.6°C)	187.6°F (86.5°C)	148.6°F (64.8°C)
6.70 g/cm <sup>3</sup> oxide	220.3°F (104.6°C)	176.8°F (80.5°C)	150.7°F (66.0°C)
<b>6.012 W/kg oxide</b>			
2.00 g/cm <sup>3</sup> oxide	350.7°F (177.1°C)	240.3°F (115.7°C)	166.7°F (74.9°C)
2.72 g/cm <sup>3</sup> oxide	399.6°F (204.2°C)	274.4°F (134.7°C)	188.4°F (86.9°C)
3.02 g/cm <sup>3</sup> oxide	406.7°F (208.1°C)	280.5°F (138.1°C)	193.3°F (89.6°C)
4.54 g/cm <sup>3</sup> oxide	414.1°F (212.3°C)	288.2°F (142.3°C)	211.5°F (99.7°C)
6.70 g/cm <sup>3</sup> oxide	352.5°F (178.1°C)	266.5°F (130.3°C)	215.6°F (102.0°C)

**TABLE XIV**  
**BNFL OUTER CONTAINER SURFACE TEMPERATURES WITH PuO<sub>2</sub>**

	Maximum container surface temperature	Average container surface temperature
<b>3.006 W/kg oxide</b>		
2.00 g/cm <sup>3</sup> oxide	107.2°F (41.8°C)	103.6°F (39.8°C)
2.72 g/cm <sup>3</sup> oxide	115.3°F (46.3°C)	110.7°F (43.7°C)
3.02 g/cm <sup>3</sup> oxide	115.0°F (46.1°C)	110.4°F (43.6°C)
4.54 g/cm <sup>3</sup> oxide	115.0°F (46.1°C)	109.3°F (42.9°C)
6.70 g/cm <sup>3</sup> oxide	114.9°F (46.1°C)	108.2°F (42.3°C)
<b>6.012 W/kg oxide</b>		
2.00 g/cm <sup>3</sup> oxide	129.1°F (54.0°C)	122.6°F (50.3°C)
2.72 g/cm <sup>3</sup> oxide	143.7°F (62.1°C)	135.2°F (57.3°C)
3.02 g/cm <sup>3</sup> oxide	143.3°F (61.8°C)	134.8°F (57.1°C)
4.54 g/cm <sup>3</sup> oxide	143.6°F (62.0°C)	132.8°F (56.0°C)
6.70 g/cm <sup>3</sup> oxide	143.9°F (62.2°C)	130.9°F (54.9°C)

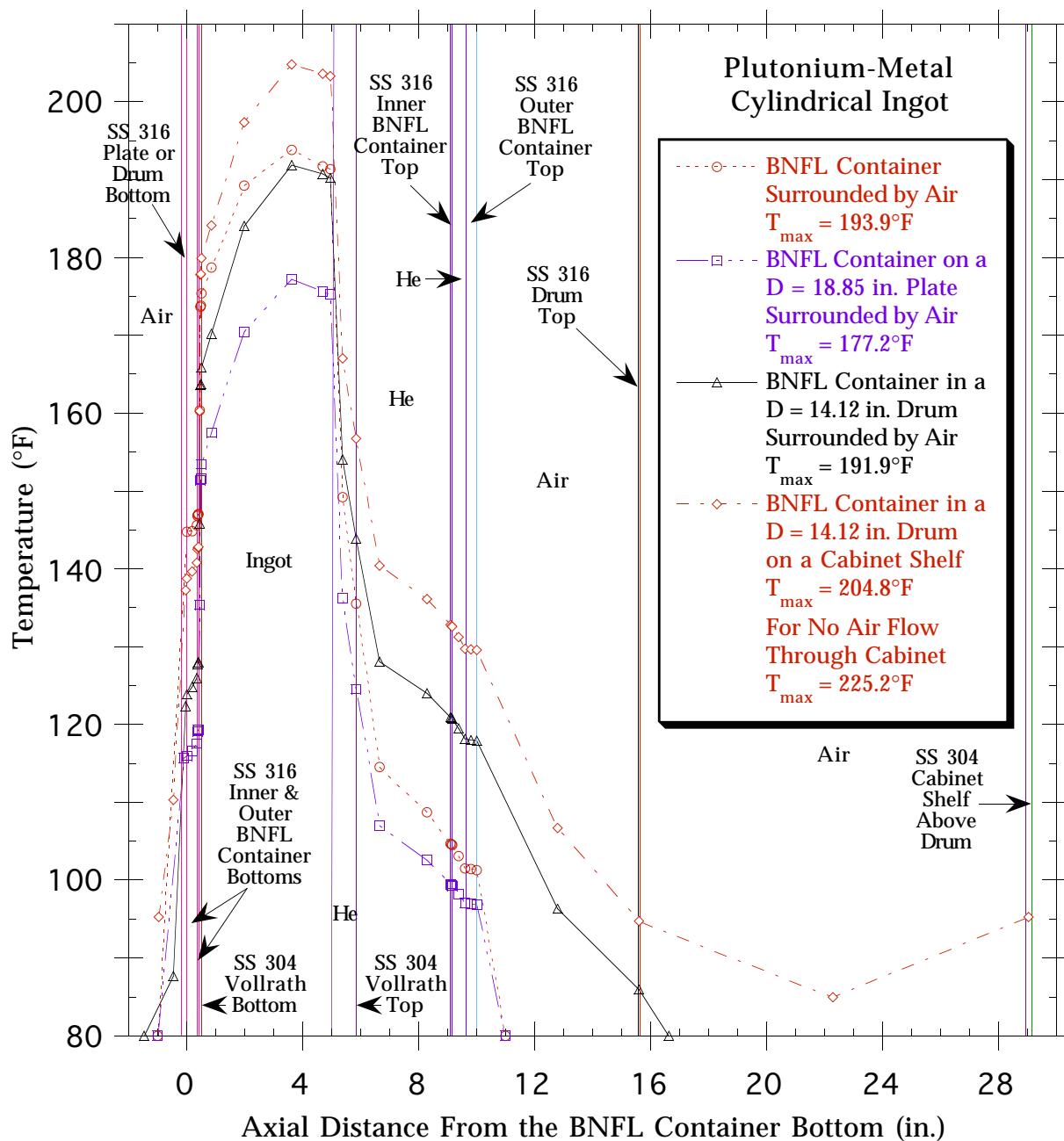


Fig. 5. Axial temperature distributions through the **plutonium-metal ingot** and container assembly for the four cases of external support structures [ $r = 2.5$  mm (0.1 in.)].

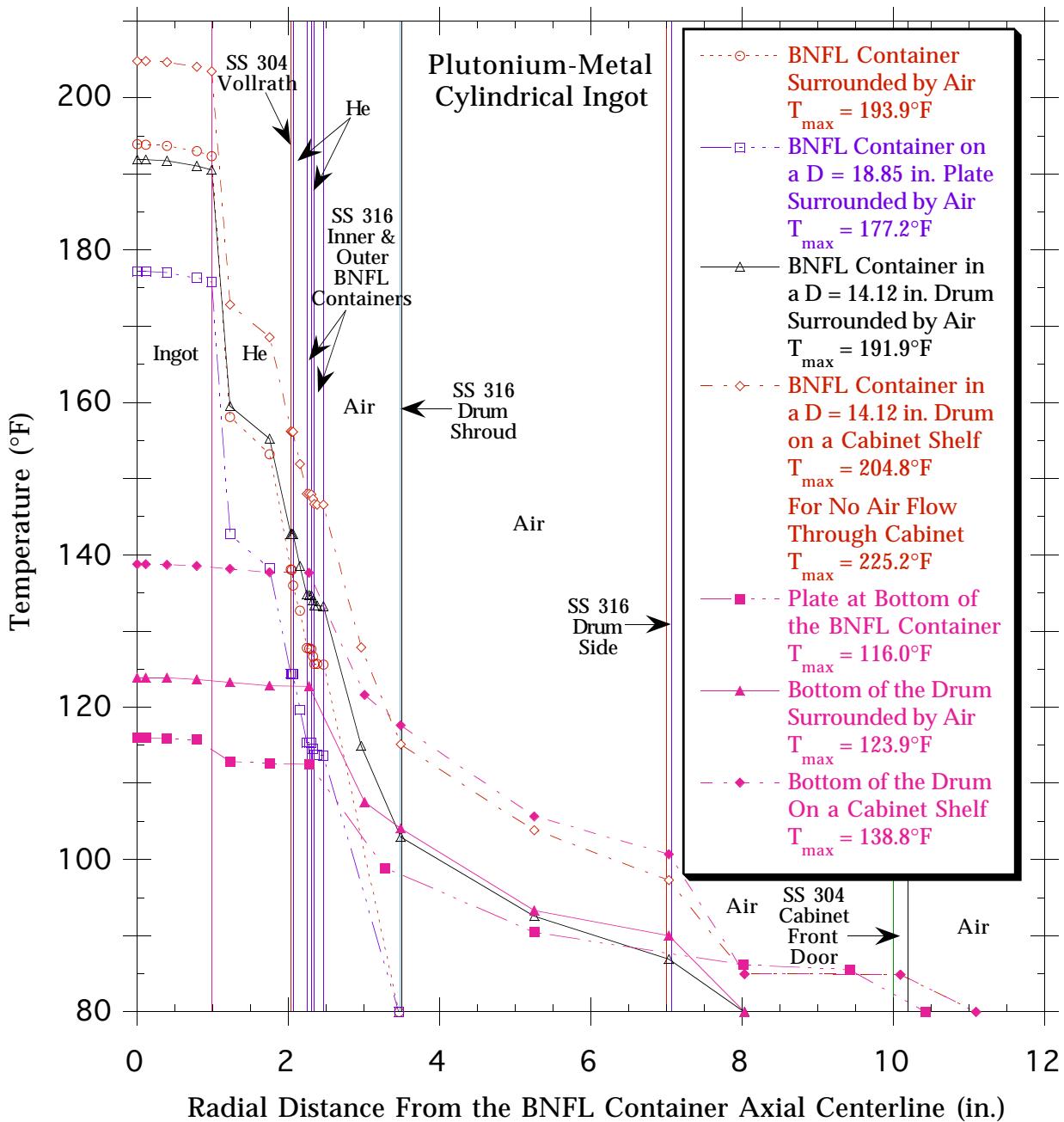


Fig. 6. Radial temperature distributions through the **plutonium-metal ingot** and container assembly for the four cases of external support structures [ $z = 92.1$  mm (3.62 in.) through the hot spot in the ingot and  $z = -2.38$  mm (-0.094 in.) for the plate or  $-0.79$  mm (-0.031 in.) for the drum].

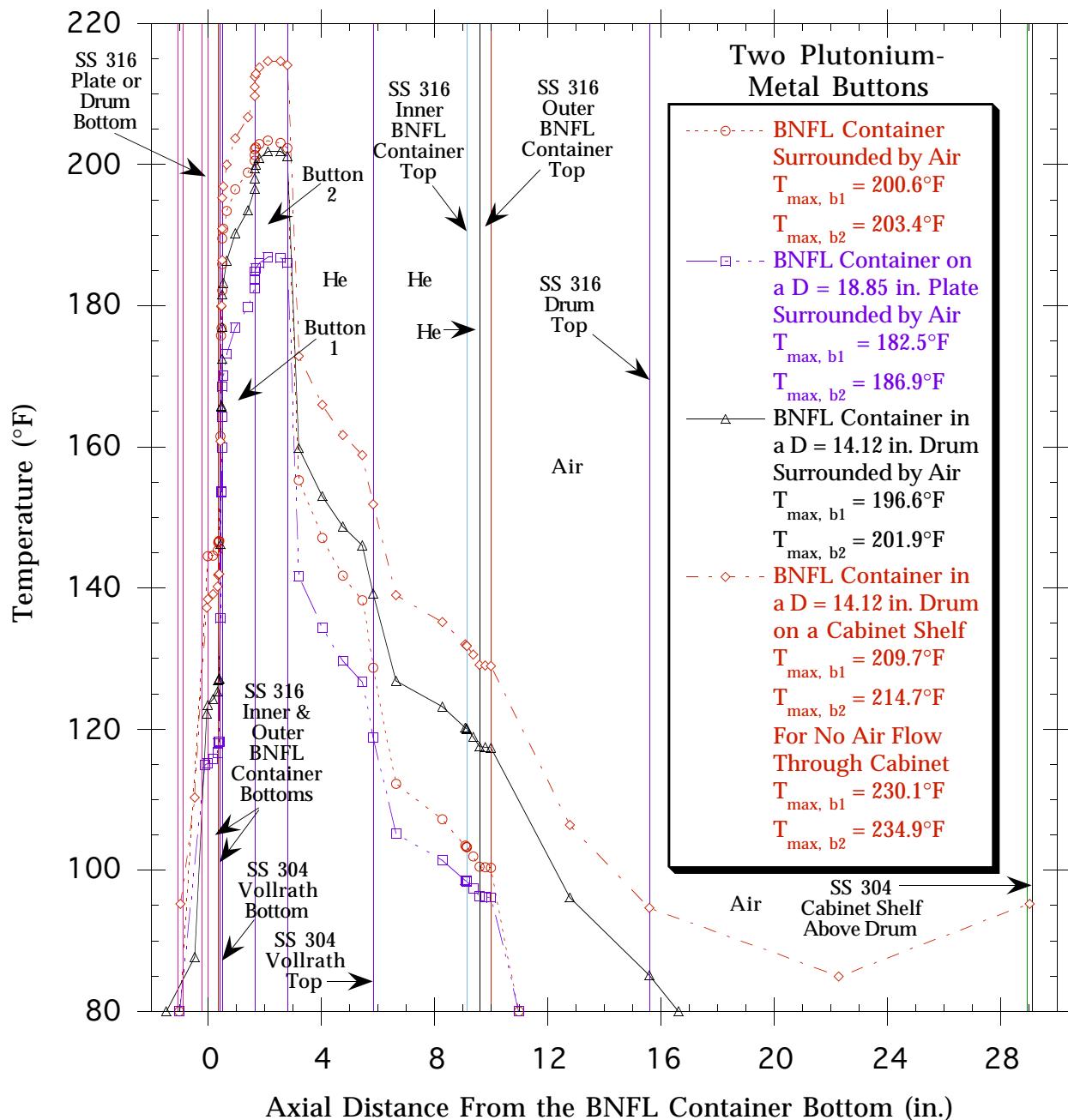


Fig. 7. Axial temperature distributions through the **two plutonium-metal buttons** and container assembly for the four cases of external support structures [ $r = 2.5$  mm (0.1 in.)].

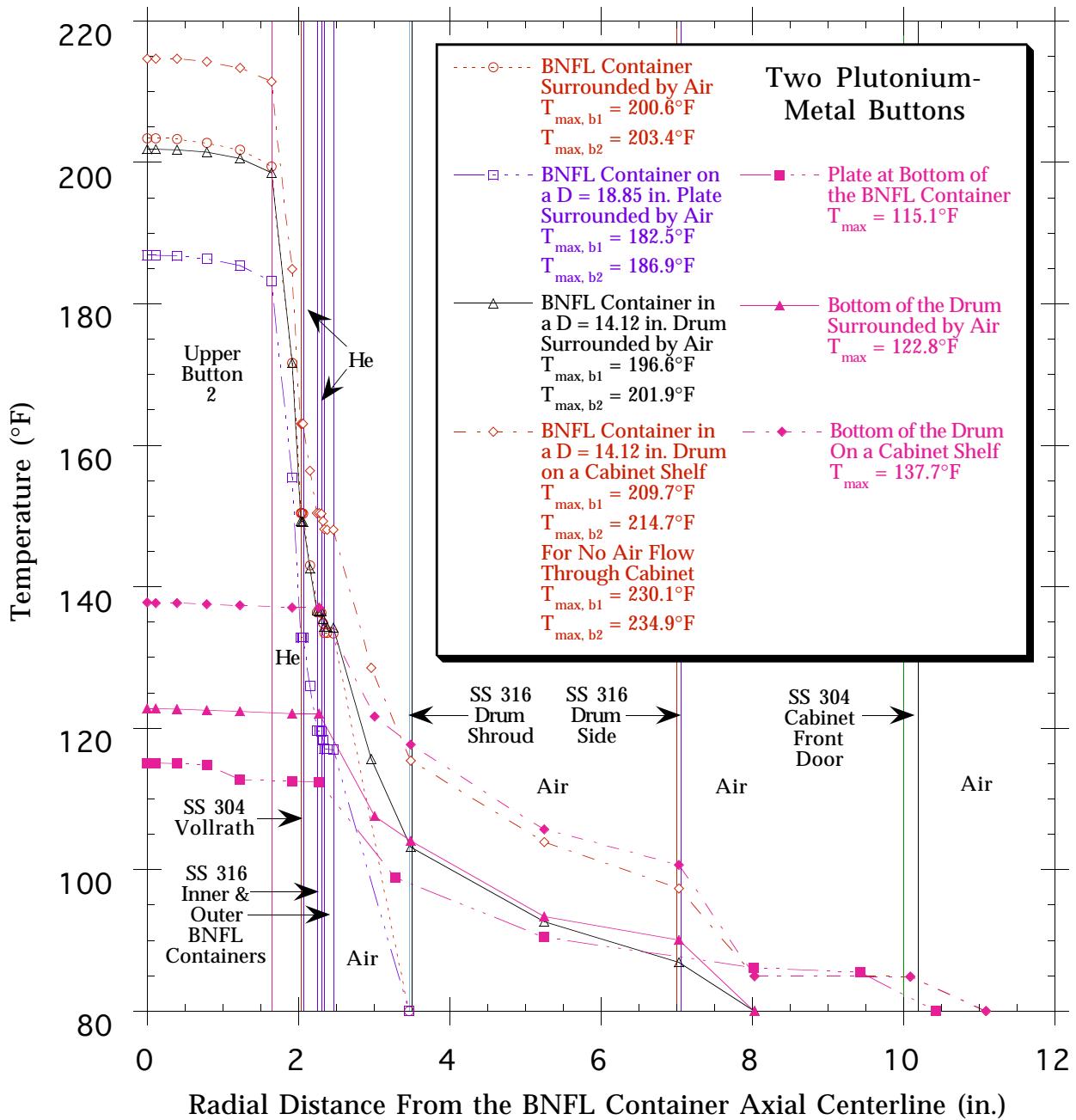


Fig. 8. Radial temperature distributions through the **two plutonium-metal buttons** and container assembly for the four cases of external support structures [through the hot spot in the upper button at  $z = 46.6$  mm (1.83 in.) for the air and plate cases and 53.7 mm (2.12 in.) for the drum and cabinet cases, and through the plate at  $z = -2.38$  mm (-0.094 in.) or through the drum bottom at  $z = -0.79$  mm (-0.031 in.) for the drum].

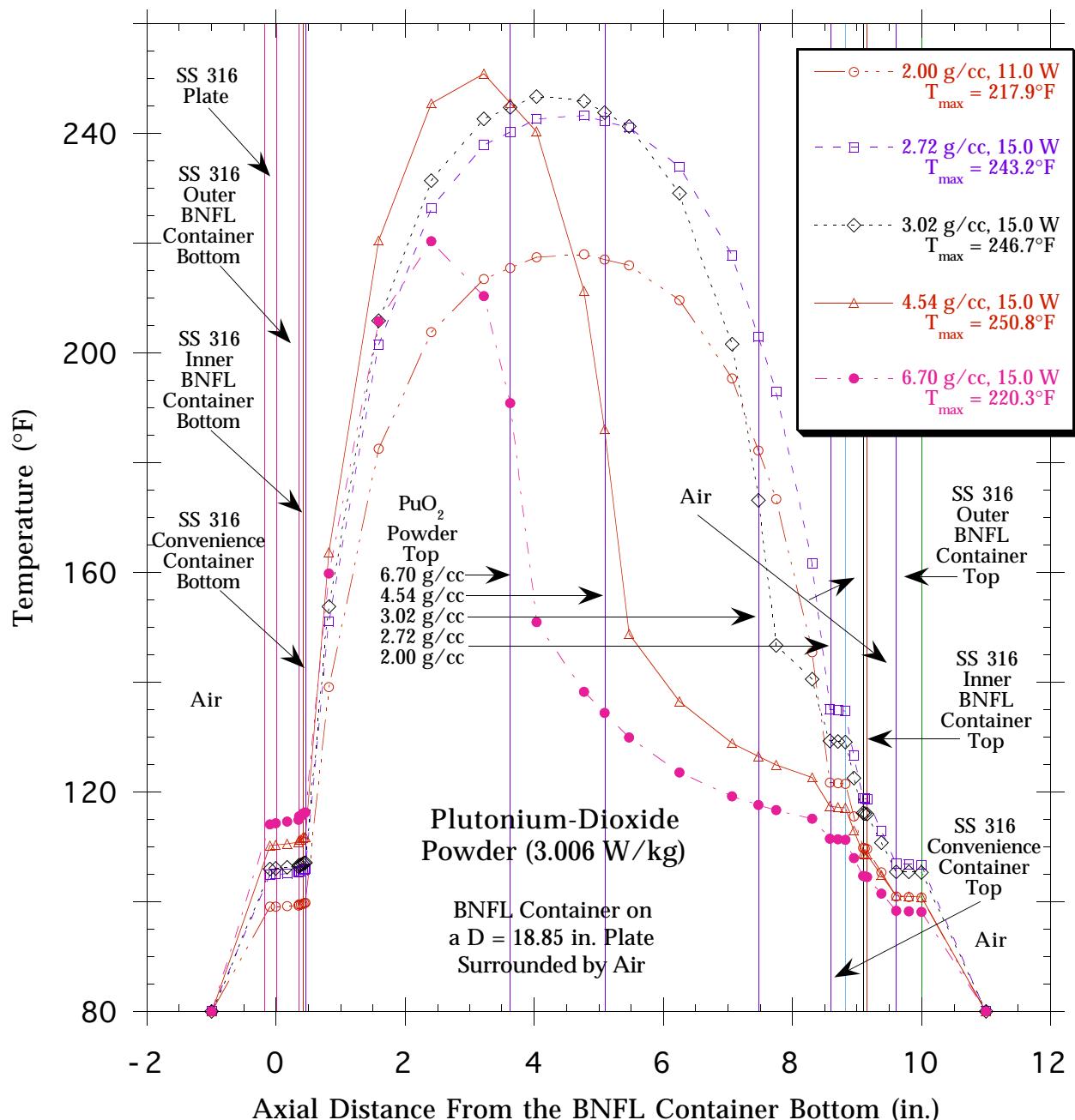


Fig. 9. Axial temperature distributions through the PuO<sub>2</sub> and container assembly for the plate case with a specific power of 3.006 W/kg of oxide [ $r = 2.5$  mm (0.1 in.)].

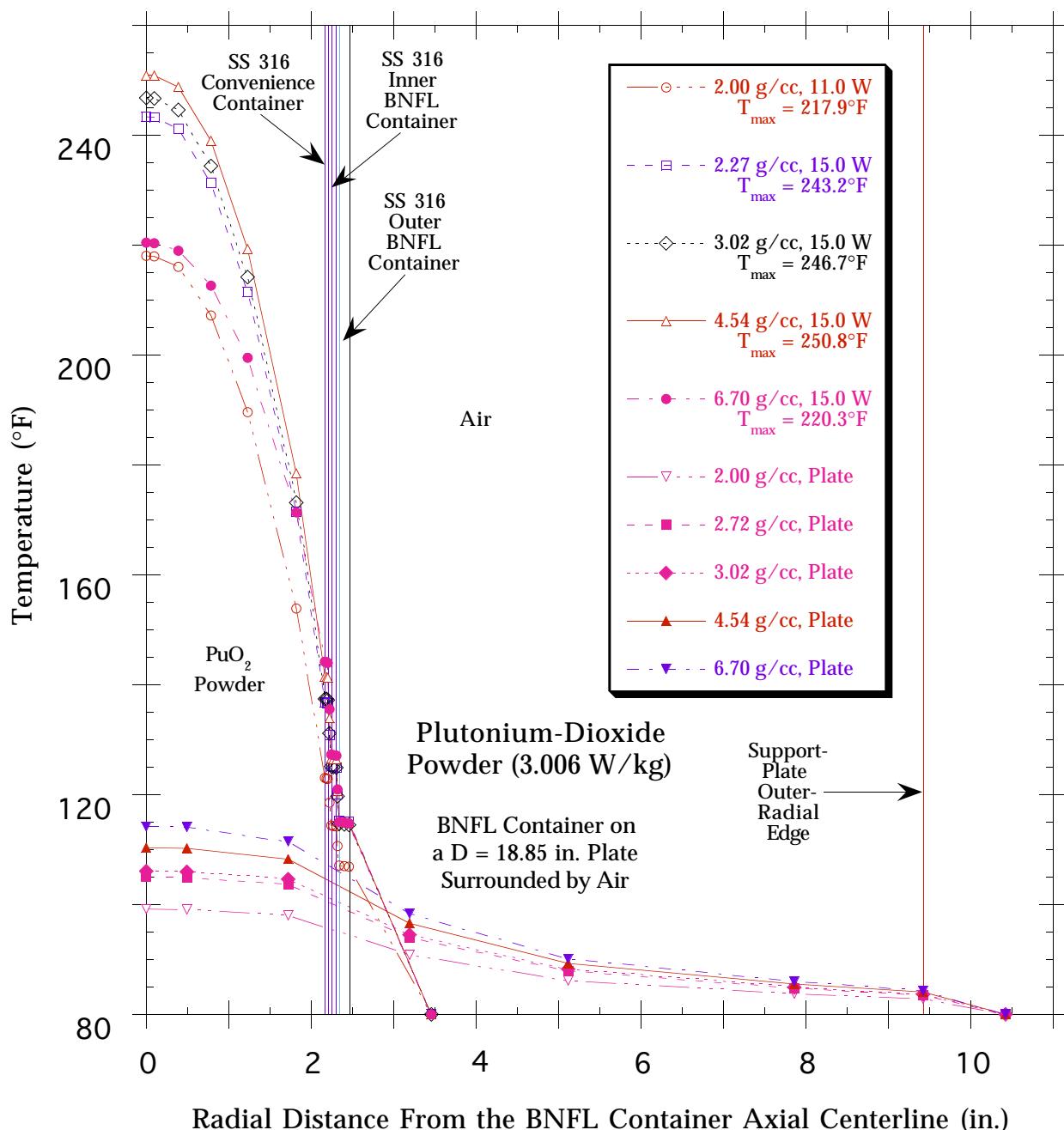


Fig. 10. Radial temperature distribution through the  $\text{PuO}_2$  and container assembly for the plate case with a specific power of 3.006 W/kg of oxide [through the hot spot in the oxide, the elevation of which varies with oxide density, and through the plate at  $z = -2.38$  mm (-0.094 in.)].

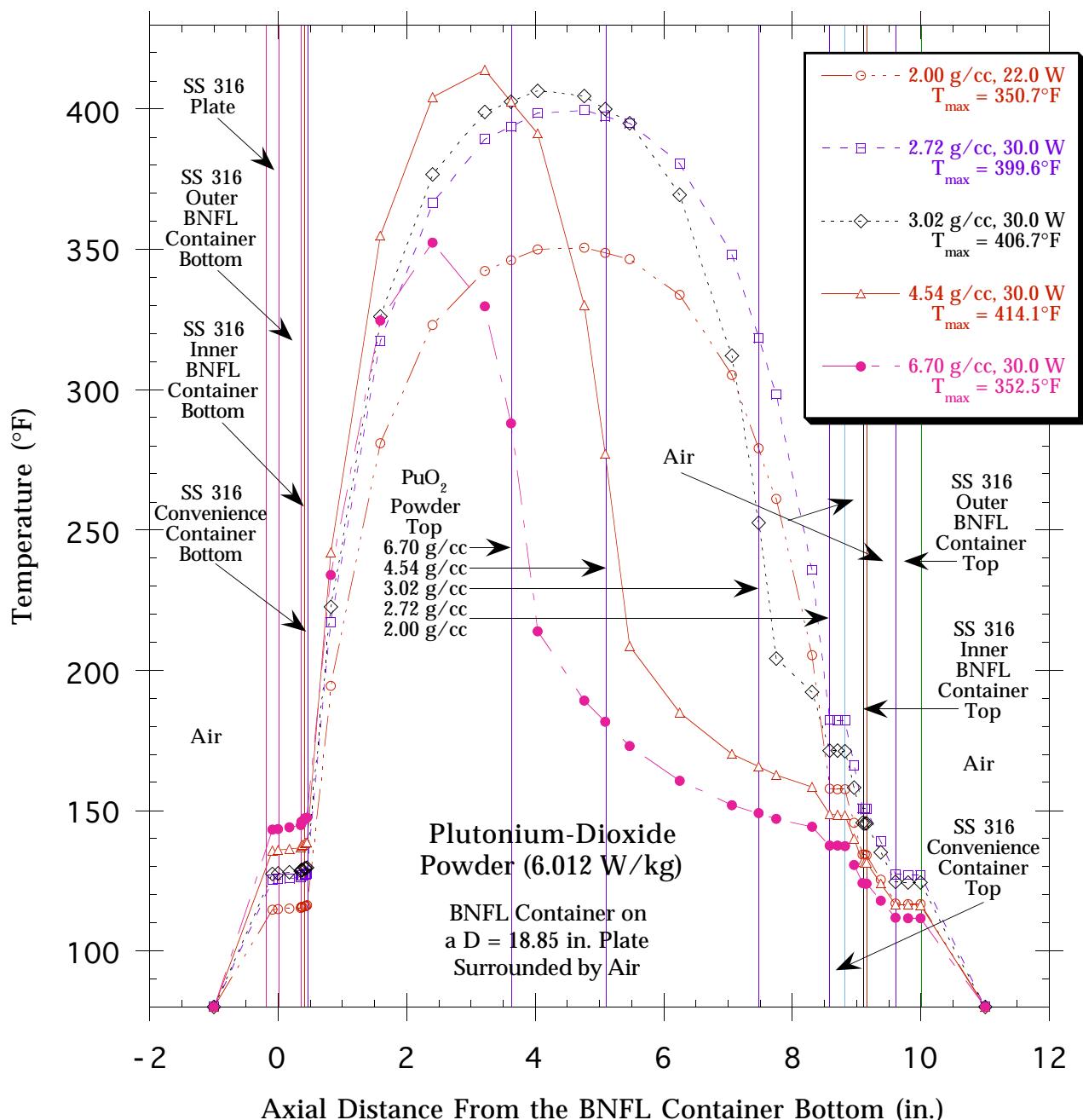


Fig. 11. Axial temperature distributions through the  $\text{PuO}_2$  and container assembly for the plate case with a specific power of 6.012 W/kg of oxide [ $r = 2.5$  mm (0.1 in.)].

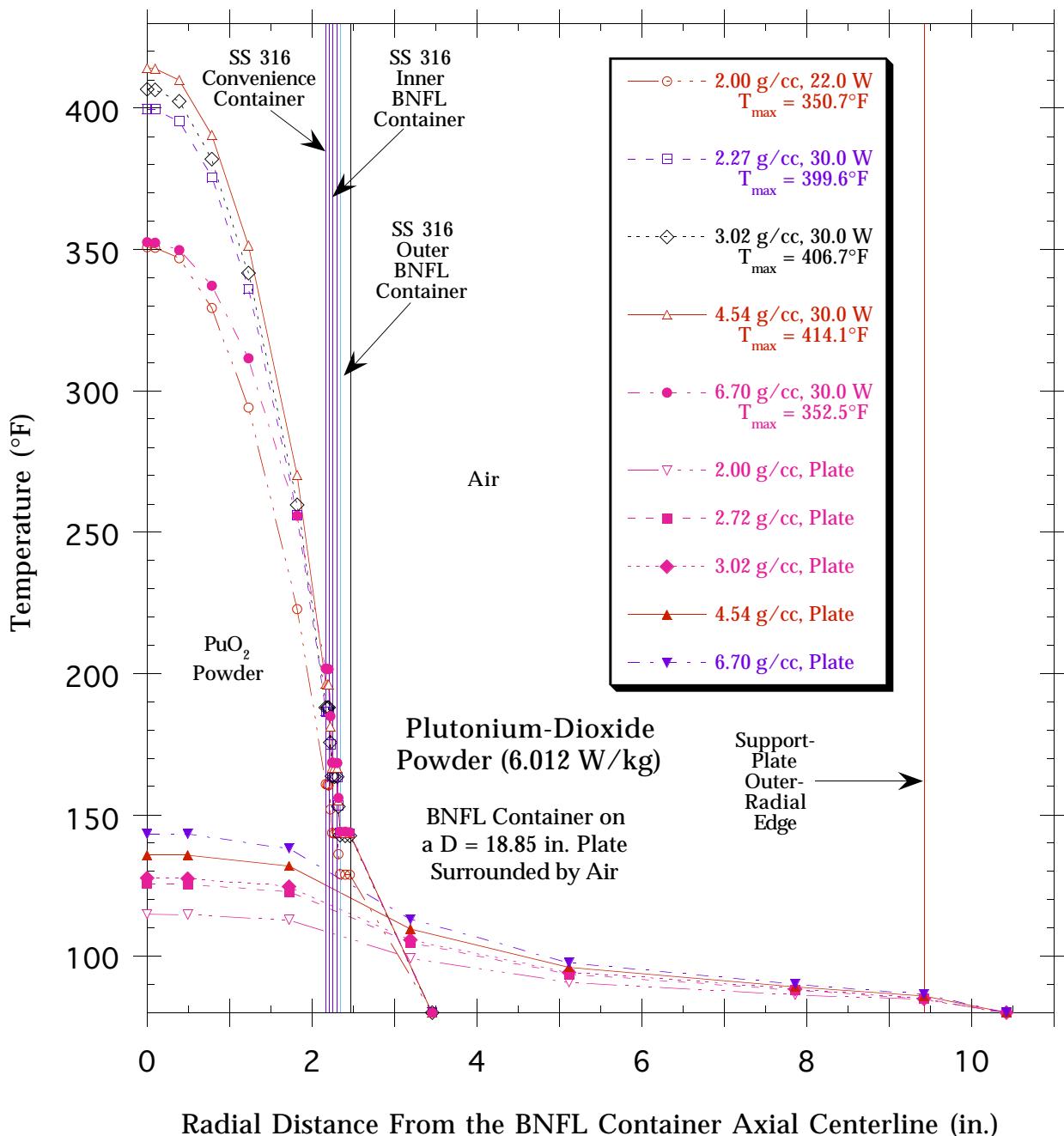


Fig. 12. Radial temperature distribution through the  $\text{PuO}_2$  and container assembly for the plate case with a specific power of 6.012 W/kg of oxide [through the hot spot in the oxide, the elevation of which varies with oxide density, and through the plate at  $z = -2.38$  mm (-0.094 in.)].

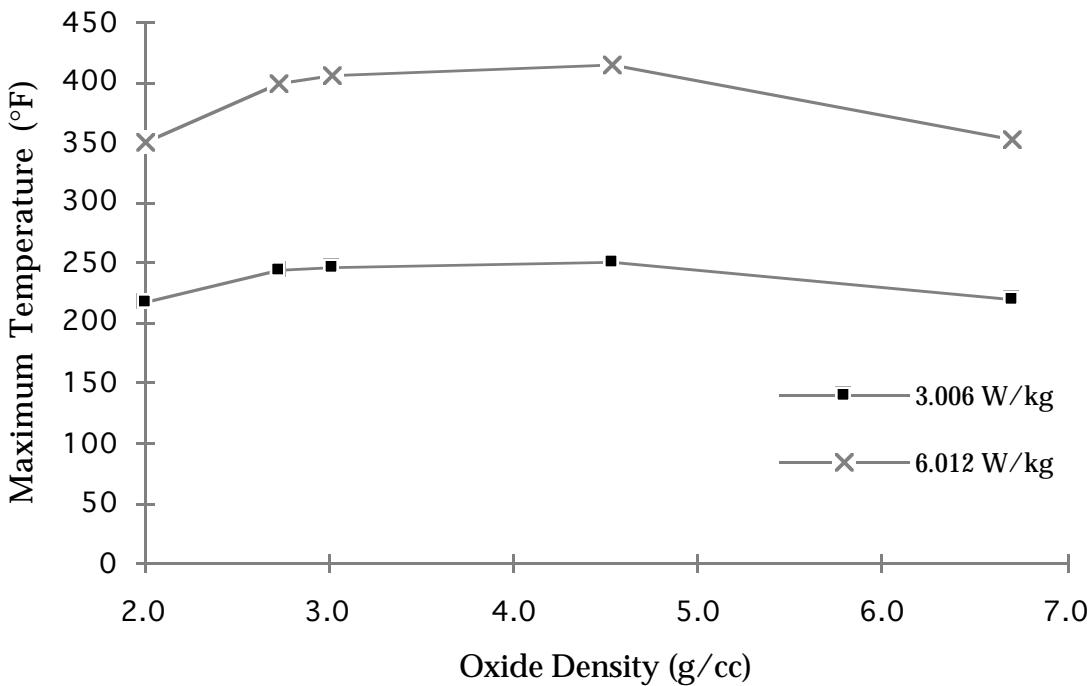


Fig. 13. Maximum temperatures in  $\text{PuO}_2$  as a function of density and specific power.

## 8.0. CONCLUSIONS

The calculated plutonium metal temperatures are high relative to the 3013 standard; margins, if they exist, are very small. If the calculated temperatures are supported by experimental data, the current design of the BNFL container system would not be sufficient by itself to meet the thermal limit imposed by the standard at 15 W. Engineered features, both inside the container and inside storage facilities, would be required to transfer the heat from the metal product to the outside of the container and then to move the heat from the container to the ultimate heat sink.

Because of the small margins between the calculated temperatures and the 3013 limit, experiment programs should be conducted to develop a database against which to benchmark the analysis tools. Ideally, these experiments should use prototypical containers and plutonium materials and should measure temperatures inside and outside the container and on the stored plutonium.

If more precision in the storage temperatures for  $\text{PuO}_2$  powders is important, then experimental programs may be required to develop a database for the thermal conductivity of the oxide powders. The thermal conductivity of oxide powders is a major uncertainty in the current analyses. Alternatively, a thorough search of the existing literature from the national laboratories may reveal that sufficient data already exist. In any event, an acceptable database should include the effects of porosity,

different fill gases, and particle size distributions. Also, we need to know if the individual oxide particles are truly solid oxide that approaches the maximum theoretical density or, alternatively, a porous solid that in itself has a reduced thermal conductivity relative to the solid oxide.

For the storage of plutonium metal, the shapes of the pieces are important. Increasing the surface-to-volume ratio, or alternatively the surface area per kg of material, should lower the temperature of the stored materials by increasing the surface area available for convective heat transfer and potentially by increasing the metal-to-metal contact area between the plutonium and the container. Both of these effects would enhance heat transfer away from the plutonium. However, fragmentation of a given mass of plutonium into smaller and smaller pieces cannot continue to the point that natural circulation of the gas is suppressed.

The structures outside the container assembly clearly have a large impact on the temperature of the stored material. Good conduction paths to transfer heat away from the container to heat sinks or to devices with large areas to enhance convection and radiation heat transfer serve to reduce the temperature of the materials. Solid wall barriers act to insulate the container assembly. To the extent possible, storage systems should reduce such barriers to improve air circulation and convective heat transfer and to maximize radiation heat transfer.

Higher heat loads are clearly detrimental. The analyses presented here demonstrate that at 15 W/container, the BNFL container system with the Vollrath convenience jar may not meet the 3013 limit for  $\alpha$ -phase plutonium in some storage situations. Higher power levels make the situation worse. Conversely, one way to meet the 3013 limit is to reduce the power level allowed per container.

Because the bottoms of the containers are flat by design, the contact areas between the BNFL inner and outer containers and between the BNFL outer container and the plate are so large that large reductions in the contact areas have only small impacts on the calculated temperatures of the stored material. However, if the manufacturing tolerances for the containers or shelves or warping during use results in these surfaces becoming significantly uneven or irregular on a macroscopic scale, the temperatures of stored materials can increase. As an example, the interference fit and resulting gap between the Vollrath jar and the inner BNFL container results in a 7–10°F (4–6°C) increase in the maximum temperatures associated with the plutonium ingot and buttons.

It appears from the analyses that helium always should be used as a fill gas for both metal pieces and oxide because its thermal conductivity is high relative to alternative gases. The high thermal conductivity of the gas improves heat transfer away from the stored product and through the narrow gaps between the walls of the containers. Argon, which is frequently described as an alternative to helium, is an unacceptable fill gas in the current container design because of its low thermal conductivity; substituting argon for helium in the calculations produces temperatures well over the 3013 limit.

Radiation heat transfer accounts for 7–8% of the heat removal from the plutonium metal cases analyzed here and for 12–22% of the heat removal from the outside of the

container. Although these contributions are relatively small, radiation heat transfer is still a significant part of the overall heat transfer given the small margins to the temperature limit in the 3013 standard. If possible, steps should be taken to maximize radiation heat transfer through appropriate surface treatments, and the effect of any surface treatment on the overall thermal response of the containers should be understood.

With regard to PuO<sub>2</sub> storage, the thermal conductivity of the oxide powder remains a large uncertainty. Small particle sizes in the powder can degrade the overall thermal conductivity through the break-away pressure effect described previously. Changing the fill gas to helium from a nitrogen-oxygen mixture may help, but the effect of particle size in combination with helium needs to be studied.

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## APPENDIX A

### PHYSICAL LIMITS FOR PLUTONIUM METAL

We met with Los Alamos plutonium experts<sup>A1</sup> to discuss plutonium properties and chemistry from a safety perspective, and this appendix provides a brief summary of that meeting. The limits presented initially at the meeting are shown in Table A-I.

In this table, “reuse” defines limits applicable to weapon parts such that the parts could be taken out of storage and reused. “Other normal storage” defines very safe limits for metal storage that assure that the form of the metal part does not change and that the container integrity is not challenged (e.g., thermal expansion of the metal part will not damage the container). Accident limits are intended to preserve the shape and crystalline structure of the metal. The  $\alpha$ -phase is the designation of the crystalline structure that relatively pure plutonium metal forms at relatively low temperatures. The  $\delta$ -phase metal normally occurs only at elevated temperatures but can be stabilized at a low temperature through alloying.

The 149°F (65°C) limit for reuse derives from historical experience with stockpile management. The application, “other normal storage,” for  $\alpha$ -phase metal [149–176°F (65–80°C)] avoids a steep increase in the thermal expansion of the metal with increasing temperature, and it certainly avoids even approaching the transition between  $\alpha$  and  $\beta$  phases.

The application, “other normal storage,” for  $\delta$ -phase metal [176–212°F (80–100°C)] is based on avoiding the chemical reaction that converts the PuO<sub>2</sub> surface film, which is corrosion resistant, into Pu<sub>2</sub>O<sub>3</sub>, which is not corrosion resistant. The microscopic structure of the surface of plutonium metal has the PuO<sub>2</sub> on the outside forming a protective layer in contact with the atmosphere, and then there is a Pu<sub>2</sub>O<sub>3</sub> layer between the PuO<sub>2</sub> and the plutonium metal. Specifying 212°F (100°C) as the limit appears to be very conservative in terms of avoiding this reaction.

**TABLE A-I**  
**BASIC TEMPERATURE LIMITS FOR PLUTONIUM METAL**

<b>Application of limit</b>	<b><math>\alpha</math>-phase</b>		<b><math>\delta</math>-phase</b>	
Reuse	149°F (65°C)		149°F (65°C)	
Other normal storage	149–176°F (65–80°C)		176–212°F (80–100°C)	
Accident	212°F (100°C)		752°F (400°C)	

The 212°F (100°C) accident limit for  $\alpha$ -phase metal is based on avoiding the  $\alpha$ - $\beta$  phase transition. This transition is “sluggish” and difficult to determine accurately.<sup>A2</sup> The  $\alpha$ - $\beta$  transition is reported as occurring nominally at 239°F (115°C) (Ref. A2) and 248°F (120°C) (Ref. A3), although it could be somewhat lower than the first value. There is 9% increase in volume (~3% change in linear dimensions) that occurs during the change from  $\alpha$  to  $\beta$  phase. Table A-II summarizes the phase changes that pure plutonium undergoes. The  $\alpha$ - $\beta$  transition is the biggest concern because of its larger volume change and the relatively low temperature at which it occurs. At temperatures below the  $\alpha$ - $\beta$  transition, there are no additional phase transitions and storage in extreme cold does not appear to be a problem. The 752°F (400°C) accident limit for  $\delta$ -phase metal avoids a Pu-Fe eutectic melting point that could lead to container failure.

Table A-III summarizes threshold temperatures for various physical and chemical processes important to plutonium metal and supports the temperature limits given in Table I. The  $\alpha$ - $\beta$  phase transition and the  $\text{PuO}_2 \Rightarrow \text{Pu}_2\text{O}_3$  chemical reactions are discussed above. Fine plutonium metal is defined as having its smallest dimension  $\leq 1$  mm, which could describe very thin plates (or foil) or irregularly shaped particles such as scrap produced during machining procedures. By contrast, bulk plutonium metal is thicker than 1 mm and can cool more readily any hot spot in the material by conduction.

**TABLE A-II  
PLUTONIUM METAL PHASE TRANSFORMATIONS**

Initial Phase	Final Phase	Temperature (°F)	Temperature (°C)	Volume change (%)
$\alpha$	$\beta$	248	120	9
$\beta$	$\gamma$	410	210	2.5
$\gamma$	$\delta$	599	315	6.9
$\delta$	$\delta'$	846	452	-0.4
$\delta'$	$\epsilon$	896	480	-2
$\epsilon$	liquid	1184	640	-1 to -2

**TABLE A-III  
PHYSICAL AND CHEMICAL PROCESSES FOR PLUTONIUM**

Physical or chemical process	Threshold temperature
$\alpha$ - $\beta$ phase transition in plutonium:	234–248°F (112–120°C)
$\text{PuO}_2 \Rightarrow \text{Pu}_2\text{O}_3$ (reduction reaction):	257–302°F (125–150°C)
Pyrophoric ignition of fine plutonium:	302–392°F (150–200°C)
Pu-Fe eutectic melting:	766°F (408°C)
Pyrophoric ignition of bulk plutonium:	842–932°F (450–500°C)
Al-Si solder melting:	853°F (456°C)
Plutonium melting:	1184°F (640°C)

Pyrophoric ignition of fine plutonium occurs at a lower temperature than for bulk plutonium because it is driven by the reduction reaction  $\text{PuO}_2 \Rightarrow \text{Pu}_2\text{O}_3$ , which releases sufficient heat to raise the temperature of the fine plutonium to the pyrophoric ignition temperature for bulk plutonium. In bulk plutonium, conduction within the metal and the mass of the metal (heat capacity) prevent the reduction reaction from heating the metal locally to the temperature required for pyrophoric ignition.

The Pu-Fe eutectic melting is a container failure mode when the plutonium and steel of the container are in contact. The Al-Si solder is actually more like a low temperature braze that is important to weapon parts.

With regard to potential limits at temperatures lower than shown in Table A-I, there appear to be no chemical reactions or crystalline changes occurring at lower temperatures that affect either  $\alpha$ -phase or  $\delta$ -stabilized plutonium. Metal samples have been cooled as low as  $-316^{\circ}\text{F}$  ( $80\text{ K}$ ) without encountering any problems such as phase transitions.

Temperature cycling is not a problem for  $\delta$ -stabilized metal. For  $\alpha$ -phase metal, temperature cycling is not a problem provided that the maximum temperature remains significantly below the  $\alpha$ - $\beta$  transition. At higher temperatures, the  $\alpha$ - $\beta$  phase transition occurs, and repeated cycling through the transition produces a more uniform orientation of the grain structure from an initial random orientation and further results in a nonuniform expansion of the material. The physical expression of this damage is in the form of micro cracking and damage to the physical shape. The transition from  $\alpha$  to  $\beta$  is very fast, on the order of seconds to minutes, but the transition from  $\beta$  to  $\alpha$  is slow, on the order of days. Therefore, long-duration temperature cycles are worse, and daily cycles may not be too bad because the transition to  $\beta$  would occur generally only once, with insufficient time for the transition back to  $\alpha$  phase.

For radiolysis reactions, an important parameter is the g-value, which is defined as the number of  $\text{H}_2$  molecules produced per 100-eV of  $\alpha$  particles. The g-value almost always falls in the range of 0.5–2.0. Because each disintegration in plutonium produces a 5.1 MeV  $\alpha$  particle, it is clear that even a small amount of plutonium can produce significant amounts of  $\text{H}_2$  through radiolysis if suitable materials are present. Radiolysis can then lead to an undesirable volume expansion through the series of chemical reactions shown in Table A-IV.

Through the series of chemical reactions in Table A-IV, plutonium metal with a density of  $16\text{--}19\text{ g/cm}^3$  ( $999\text{--}1186\text{ lb}_m/\text{ft}^3$ ) can be converted to an oxide with a density of  $6.5\text{ g/cm}^3$  ( $406\text{ lb}_m/\text{ft}^3$ ), which is roughly a factor of 3 increase in volume.

The physical processes described above suggest that the  $212^{\circ}\text{F}$  ( $100^{\circ}\text{C}$ ) temperature limit specified in the 3013 standard for  $\alpha$ -phase plutonium metal should not be relaxed without careful study of the impacts of the phase change on container integrity and of the subsequent loss of the structural integrity of the plutonium metal on long-term storage and retrieval operations. For  $\delta$ -stabilized plutonium, and if the  $212^{\circ}\text{F}$  ( $100^{\circ}\text{C}$ ) limit for  $\alpha$ -phase plutonium is modified or removed, there are chemical reactions with

**TABLE A-IV**  
**CHEMICAL PROCESSES RESULTING FROM RADIOLYSIS**

Chemical reaction	Comment
$-\text{CH}_2^- + \alpha \Rightarrow -\text{C}^- + \text{H}_2$ (gas)	This reaction results in plastic becoming brittle.
$\text{H}_2 + \text{Pu} \Rightarrow \text{PuH}_2$	$\text{PuH}_2$ is pyrophoric in an oxygen-containing atmosphere.
$\text{O}_2$ or $\text{N}_2 + \text{PuH}_2 \Rightarrow \text{PuO}_2$ or $\text{PuN} + \text{H}_2$	This reaction means that $\text{N}_2$ is not a good inerting atmosphere for plutonium metal.
$\text{H}_2 + \text{Pu} \Rightarrow \text{PuH}_2$	This repeated reaction recycles the hydrogen in the hydride and propagates into the plutonium metal as long as oxygen or nitrogen gas is available.

threshold temperatures that could set new limits starting at ~250°F (121°C) that apply regardless of the crystalline structure of the metal.

## REFERENCES

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## APPENDIX B

### DESCRIPTIONS OF THE TSAP CODE AND INPUT MODELS

The analysis methodology used to evaluate the temperature distribution for all the cases defined previously is described in many basic heat-transfer text books, such as Ref. B1 and B2, and is referred to as the nodal network representation or resistance formulation. The methodology involves dividing the complete geometry of the problem, including all solid materials and all gas-filled regions, into a series of volume nodes and surface nodes and then connecting the various nodes with appropriate heat-transfer processes. A basic assumption is that the nodal network resolves the physical geometry in sufficient detail so that the node temperature, a single value for each node, is an acceptable approximation of the temperature for the entire volume of the node. A surface node is a degenerate volume node that has area but no volume and hence cannot store thermal energy. The time rate of change in thermal energy of node i can be represented as

$$\text{thermal-energy storage rate} = \rho_i \cdot c_{p,i} \cdot V_i \cdot \frac{\partial T_i}{\partial t}, \quad (B1)$$

where

$t$	= time (s);
$T_i$	= temperature (K) of node i;
$V_i$	= volume ( $m^3$ ) of node i;
$\rho_i$	= material density ( $kg/m^3$ ) of node i; and
$c_{p,i}$	= specific heat at constant pressure [ $J/(kg \cdot K)$ ] of node i.

The thermal energy of a node can be changed by heat generation within the node or by any of the three heat-transfer processes at the surface of the node: conduction, convection, and radiation where

$$\text{heat generation inside the node} = Q_i ; \quad (B2)$$

$$\begin{aligned} \text{conduction heat transfer} &= k_{ij} \cdot A_{\text{cond},ij} \cdot \frac{\partial T}{\partial x} \\ &\equiv k_{ij} \cdot A_{\text{cond},ij} \cdot \frac{T_j - T_i}{\Delta x_{ij}} ; \end{aligned} \quad (B3)$$

$$\text{convection heat transfer} = h_{ik} \cdot A_{\text{conv},ik} \cdot (T_k - T_i) ; \quad (B4)$$

and

$$\text{radiation heat transfer} = \bar{\epsilon}_{il} \cdot \sigma \cdot A_{\text{rad},i} \cdot f_{i-l} \cdot (T_l^4 - T_i^4) ; \quad (B5)$$

where

$Q_i$	= heat generation (W) in node i;
$T_j, T_k, T_l$	= temperatures (K) of nodes j, k, and l, respectively;
$x$	= a line between the centers of nodes i and j;
$\Delta x_{ij}$	= distance between the centers of nodes i and j;
$A_{cond,ij}$	= area ( $m^2$ ) between nodes i and j available for conduction;
$A_{conv,ik}$	= area ( $m^2$ ) between nodes i and k available for convection;
$A_{rad,i}$	= exposed area ( $m^2$ ) of node i available for radiation heat transfer;
$k_{ij}$	= thermal conductivity [ $W/(m \cdot K)$ ] between nodes i and j;
$h_{ik}$	= convective heat-transfer coefficient [ $W/(m^2 \cdot K)$ ] between nodes i and k;
$\bar{\varepsilon}_{il}$	= effective emissivity (dimensionless) for radiation heat transfer between nodes i and l $= \frac{1}{\frac{1}{\varepsilon_i} + \frac{1}{\varepsilon_l} - 1};$
$\varepsilon_i, \varepsilon_l$	= surface emissivities (dimensionless) for radiation heat transfer for nodes i and l;
$\sigma$	= Stefan-Boltzmann constant $= 5.6687 \cdot 10^{-8} W/(m^2 \cdot K^4)$ ; and
$f_{il}$	= radiation-heat-transfer view factor (or shape factor) (dimensionless) from surface of node i to the surface of node l.

Note that in Eq. (B3) above, the temperature gradient has been approximated by a finite difference. In practice, the time derivative in Eq. (B1) would also be replaced by a finite difference. In an analogy to electrical networks, thermal resistances are  $\Delta x/(k \cdot A)$  and  $1/(h \cdot A)$ .

The five equations above can be combined as follows to describe the temperature of node i in terms of the temperatures at other nodes:

$$\rho_i \cdot c_{p,i} \cdot V_i \cdot \frac{\partial T_i}{\partial t} = Q_i + \sum_j^{\text{paths}} k_{ij} \cdot A_{cond,ij} \cdot \frac{T_j - T_i}{\Delta x_{ij}} + \sum_k^{\text{paths}} h_{ik} \cdot A_{conv,ik} \cdot (T_k - T_i) + \sum_l^{\text{paths}} \bar{\varepsilon}_{il} \cdot \sigma \cdot A_{rad,i} \cdot f_{il} \cdot (T_l^4 - T_i^4) . \quad (B6)$$

The summations in Eq. (B6) are over all conduction, convection, and radiation paths as indicated. Convection paths are limited to the coupling between a solid node (or the surface node between a solid and gas node) and an immediately adjacent gas node because the heat-transfer coefficient  $h$  defines a surface process. As used in this report, the radiation paths describe radiation heat transfer between solid (or surface) nodes that are separated by gas nodes. Furthermore, the current analyses assume that the gas is transparent to thermal radiation.

Approximating the time derivative in Eq. (B6) with a finite difference results in a coupled set of simultaneous, algebraic equations that describe the temperature field in both space and time. Each equation conserves thermal energy for that particular node. Setting the time-derivative to zero produces a steady-state set of equations. All of the calculated results in this report are for steady state.

The above discussion has defined the physical parameters and constants in terms of SI units because of the consistent definitions of the units. Obviously, engineering units can be used with appropriate conversion factors added to the equations.

### B.1. TSAP Code

The Thermal System Analysis Program<sup>B3</sup> (TSAP) provides a solution algorithm for the system of equations defined by Eq. (B6). TSAP is actually two programs: a preprocessor (PRETSAP) and a solver (EXCTSAP). TSAP is programmed in FORTRAN with 64-bit, double precision, real-valued variables. Reference B4 demonstrates the correct programming and accuracy of the code through comparisons to known, analytic solutions. The code executes on a variety of computers, and we ran the calculations described in this report on a Sun SPARCstation 20 and a Sun SPARCstation 2.

TSAP solves directly the network matrix of simultaneous, linear, algebraic equations when only conduction and convection are present and when properties are constant (no temperature feedback). When radiation heat transfer and/or temperature-dependent properties are included in the calculation, the code uses a Newton's method iterative solution with a Jacobian matrix form of the network equations. For the analyses in this report, the convergence criterion for node temperatures was  $1.0 \cdot 10^{-6}^{\circ}\text{C}$  ( $1.8 \cdot 10^{-6}^{\circ}\text{F}$ ). When compared with a test case in which the convergence criterion was reduced 4 orders of magnitude to  $1.0 \cdot 10^{-10}^{\circ}\text{C}$  ( $1.8 \cdot 10^{-10}^{\circ}\text{F}$ ), the calculated temperatures changed by  $<1.0 \cdot 10^{-4}^{\circ}\text{C}$  ( $1.0 \cdot 10^{-4}^{\circ}\text{F}$ ). (The code printed temperatures only to this accuracy, and the actual differences may have been even less.)

The input for TSAP is structured as follows:

1. Problem title on the first line;
2. COND DMOD, an indicator that cards defining the nodes follow;
3. Sufficient lines to define all of the nodes, each line defining a node number  $i$ , initial temperature  $T_i$ , specific heat  $c_{p,i}$ , density  $\rho_i$ , volume  $V_i$ , and power  $Q_i$ ;

4. ENDD, a flag indicating the end of the input defining nodes;
5. COND DMOD, an indicator that lines defining the heat-transfer paths follow;
6. Sufficient lines to define all of the heat-transfer paths, each line defining a path number  $j$  (negative valued for radiation path), node  $m$  on one side, node  $n$  on the other side, thermal conductivity  $k_{mn}$  or heat-transfer-coefficient  $h_{mn}$  or effective emissivity  $\bar{\epsilon}_{mn}$ , appropriate area  $A_{\text{conduction},mn}$  or  $A_{\text{convection},mn}$  or  $A_m$  (for radiation), and length  $\Delta x_{ij}$  for conduction or 1.0 for convection or view factor  $f_{m-n}$  for radiation;
7. ENDD, a flag indicating the end of the cards defining paths;
8. CNTL DATA, an indicator that cards with control information for TSAP follow;
9. Lines defining various control information, including the temperature convergence criterion;
10. ENDD, a flag indicating the end of the control data;
11. Sections of input defining FORTRAN-coded subroutines VAB1, VAB2, and VAB3 that allow the user to define features like temperature feedback, to calculate and write additional information about the results, etc.

In the sections of input defining the nodes and the heat-transfer paths, lines starting with COMM are comments and do not affect the calculation.

We used TSAP in a mode that required SI units for the input as defined previously. The exceptions were that time  $t$  was in hours (requirement of TSAP), specific heat  $c_p$  was in  $\text{W}\cdot\text{h}/(\text{kg}\cdot\text{K})$ , and temperature  $T$  was in  $^{\circ}\text{C}$  (TSAP's version of SI units). Because temperatures are calculated in  $^{\circ}\text{C}$ , the code internally converts the temperatures to K when calculating the radiation heat transfer defined in Eq. (B5).

**B.1.1. Treatment of Conduction Heat Transfer.** The individual conduction paths are defined by Eq. (B3). From the geometry we must supply both the area  $A_{\text{conduction},ij}$  and the length  $\Delta x_{ij}$  between the node centers. In defining the models, we assumed axial symmetry (no azimuthal variation) and generally maintained an orthogonal r-z coordinate system. When we developed the node structure for the cabinet case described in Section 3 of the main report, we maintained the axial symmetry assumption from the stored material through the storage drum but then represented the cabinet itself in coarsely-noded three dimensions.

The area  $A_{\text{conduction},ij}$  is always the interface area common to the two nodes. The  $\Delta x_{ij}$  term is always a measure of the distance between the node centers. We have defined the  $\Delta x_{ij}$  as follows:

$$\Delta x_{ij} = \Delta z \text{ for axial directions} \quad (B7)$$

or

$$\Delta x_{ij} = r \cdot \ln(r_j/r_i) \text{ for radial directions for } r_i < r_j , \quad (B8)$$

where  $\Delta z$  is the axial distance between node centers,  $r$  is the radius to the interface,  $r_j$  is the radius to the center of the node outside the surface, and  $r_i$  is the radius to the center of the node inside the surface. When the node structure deviates from an orthogonal  $r$ - $z$  coordinate system, such as when the nodes are detailing the container wall through the curved transition from the container bottom to the container side, approximations had to be made to Eqs. (B7) and (B8) on a case-by-case basis.

**B.1.2. Treatment of Convection Heat Transfer.** Equation (B4) defines the terms for convection heat transfer. In this form, the term is only applicable to heat transfer from a solid surface to a gas. The area  $A_{\text{convection},ik}$  corresponds to the common interface area between the two nodes. The convection-heat-transfer term is very similar to the conduction-heat-transfer when  $\Delta x_{ik}$  is set identically to 1.0, and TSAP requires setting  $\Delta x_{ik}$  to 1.0 to model convection heat transfer from a solid surface.

**B.1.3. Treatment of Bulk Convective Heat Transfer in Gas Spaces.** The TSAP code lacks the necessary fluid-transport modeling to represent correctly the heat transfer associated with the movement of gas. However, the addition of heat into a gas space can result in buoyancy-driven flows that produce better, or enhanced, heat transfer within the gas relative to that produced by conduction alone. To compensate for this deficiency, we model bulk convective heat transfer between gas nodes with the standard conduction path described in subsection 5.1.1 above and increase the thermal conductivity of the gas by an enhancement factor. In the input, the specified thermal conductivity of the gas is the actual thermal conductivity times the enhancement factor.

We have used the enhancement factors shown in Table B-I for all of the gases involved in the calculations. The magnitudes of these enhancement factors are not well known, and we have based them on previous analyses and on convective heat transfer.

**B.1.4. Treatment of Radiation Heat Transfer.** Radiation heat transfer between nodes representing solid surfaces and separated by gas is described by Eq. (B5). As indicated previously, the TSAP input specifies radiation paths by setting the path number to a negative value. The individual emissivities  $\varepsilon_i$  and  $\varepsilon_l$  are surface properties of the solid

**TABLE B-I**  
**ENHANCEMENT FACTORS FOR MODELING**  
**CONVECTION BETWEEN ADJACENT GAS-FILLED NODES**

Situation	Enhancement factors
Inside convenience jar	10.0
Narrow gaps between containers	1.0
Open regions inside the containers	5.0
Open regions inside the storage drum	5.0
Open regions inside the cabinet to the side of the drum	10.0
Open region at the top of the cabinet	2.0

materials, and the view factor  $f_{i-l}$  is a function of the geometry defined by the following double integral:

$$f_{i-l} = \frac{1}{A_i} \int \int \frac{\cos \theta_i \cdot \cos \theta_l \cdot dA_i \cdot dA_l}{\pi \cdot x^2} , \quad (B9)$$

where  $A_i$  and  $A_l$  are the surface areas of nodes  $i$  and  $l$ , respectively,  $x$  is the straight-line distance between the centers of area increments  $dA_i$  and  $dA_l$ , and  $\theta_i$  and  $\theta_l$  are the angles between lines perpendicular to  $dA_i$  and  $dA_l$  and  $x$ . Reference B5 describes the numerical evaluation of Eq. (B9).

**B.1.5. User FORTRAN.** The user-specified FORTRAN allows the user to introduce temperature dependence into selected thermal conductivities and heat-transfer coefficients and also defines special edits and summaries of the calculated results. TSAP calls subroutine VAB1 at the beginning of every iteration, and we used this subroutine to specify temperature dependent properties for the gases and for plutonium metal. As a part of the evaluation of gas properties, we evaluated the heat-transfer coefficients  $h_{ik}$  based on correlations for selected paths and determined if the

convection heat-transfer process was conduction limited. We used subroutine VAB3 to search for maximum and minimum temperatures, to calculate average temperatures, to sum the heat transfer over various surfaces, and to determine the relative contribution of each heat-transfer mode for the stored material (plutonium metal or  $PuO_2$ ) and for the outside of the BNFL container. Because of the limited amount of information stored by TSAP and made available to the VAB1, VAB2, and VAB3 subroutines, the user FORTRAN is generally hard-wired to a particular problem.

## B.2. Required Thermal Properties and Heat-Transfer Coefficients

We used the temperature-dependent gas properties to evaluate the correlations for heat-transfer coefficients  $h_{ik}$ . Correlations, curve fits of tabulated data, and the ideal gas law specified gas properties for air, helium, and argon as functions of temperature. A curve fit of data specified the thermal conductivity of plutonium metal as a function of temperature.

**B.2.1. Thermal Properties for Plutonium Metal.** The thermal conductivity  $k_{ij}$  for plutonium metal was defined by the following curve fit:

$$k_{ij} = 6.15856 + 2.11264 \cdot 10^{-2} \cdot T + 2.0 \cdot 10^{-5} \cdot T^2 , \quad (B10)$$

where  $T$  is average temperature in °C between the two nodes  $i$  and  $j$ . Equation (B10) is a fit to data from Ref. B6.

**B.2.2. Gas Properties and Heat-Transfer Coefficients.** In addition to the previously used properties  $k$ ,  $c_p$ , and  $\rho$ , the evaluation of heat-transfer coefficients requires the fluid viscosity  $\mu$ . The following gas properties were used in the analyses to define the heat-transfer coefficients:

### Helium

$$k [W/(m·K)] = 3.3366 \cdot 10^{-3} \cdot [(T_i + T_k)/2 + 273.16]^{0.668} \quad (B11)$$

$$c_p [W·h/(kg·K)] = 1.4539 \quad (B12)$$

$$\mu [\text{kg}/(\text{m} \cdot \text{h})] = 6.8531 \cdot 10^{-2} + 7.85947 \cdot 10^{-5} \cdot (T_i + T_k) - 1.38105 \cdot 10^{-8} \cdot (T_i + T_k)^2 \quad (B13)$$

$$\rho (\text{kg}/\text{m}^3) = 48.792 / [(T_i + T_k)/2 + 273.16] \quad (B14)$$

### Air

$$k [W/(m·K)] = 2.3991 \cdot 10^{-2} + 3.30685 \cdot 10^{-5} \cdot (T_i + T_k) - 3.49125 \cdot 10^{-9} \cdot (T_i + T_k)^2 \quad (B15)$$

$$c_p [W·h/(kg·K)] = 2.7625 \cdot 10^{-1} + 2.72465 \cdot 10^{-5} \cdot (T_i + T_k) - 1.36857 \cdot 10^{-9} \cdot (T_i + T_k)^2 \quad (B16)$$

$$\mu [\text{kg}/(\text{m} \cdot \text{h})] = 6.1474 \cdot 10^{-2} + 1.06686 \cdot 10^{-4} \cdot (T_i + T_k) - 7.3260 \cdot 10^{-8} \cdot (T_i + T_k)^2 \quad (B17)$$

$$\rho (\text{kg}/\text{m}^3) = 353.08 / [(T_i + T_k)/2 + 273.16] \quad (B18)$$

### Argon

$$k [W/(m·K)] = 1.644 \cdot 10^{-2} + 5.115 \cdot 10^{-5} \cdot (T_i + T_k)/2 - 2.65 \cdot 10^{-8} \cdot [(T_i + T_k)/2]^2 \quad (B19)$$

$$c_p [J/(kg·K)] = 0.66 \cdot k/\mu \quad (B20)$$

$$\mu [\text{kg}/(\text{m} \cdot \text{s})] = 2.09 \cdot 10^{-5} + 5.95 \cdot 10^{-8} \cdot (T_i + T_k)/2 - 3.5 \cdot 10^{-11} \cdot [(T_i + T_k)/2]^2 \quad (B21)$$

$$\rho (\text{kg}/\text{m}^3) = 487.4 / [(T_i + T_k)/2 + 273.16] \quad (B22)$$

where  $T_i$  and  $T_k$  are the temperatures of the nodes connected by the heat-transfer path. All helium properties and the air properties  $\mu$  and  $\rho$  are based on Ref. B7. Air properties  $k$  and  $c_p$  are conversions of the functions THCNT and HCAP in TSAPLIB.<sup>B3</sup> The argon properties  $k$ ,  $\mu$ , and the Prandtl number (Pr) are curve fits of limited data in Ref. B8, with  $c_p$  backed out from the definition of the Pr number. Argon  $\rho$  is based on a single density from Ref. B9.

Natural-convection heat transfer between a solid surface and the adjacent gas is generally expressed as a Nusselt number  $Nu$  correlated as a function of the Grashoff number  $Gr$  and the Prandtl number  $Pr$ . The heat-transfer coefficient  $h$  is related to the  $Nu$  through the definition of  $Nu$ :

$$h = Nu \cdot \frac{k}{L} , \quad (B23)$$

where  $h$  is the heat-transfer coefficient,  $k$  is the thermal conductivity of the gas, and  $L$  is a characteristic length that depends on the particular correlation and geometry. The  $Gr$  and  $Pr$  numbers are defined as

$$Gr = \frac{g \cdot \beta \cdot (T_{\text{surface}} - T_{\text{fluid}}) \cdot L^3}{(\mu/\rho)^2} \quad (\text{B24})$$

and

$$Pr = \frac{c_p \cdot \mu}{k} , \quad (\text{B25})$$

where  $g$  is acceleration due to gravity,  $\beta$  is the volume coefficient of thermal expansion for the fluid ( $1/T_{\text{absolute}}$  for an ideal gas),  $L$  is the same characteristic length defining the  $Nu$  number, and  $c_p$ ,  $\mu$ , and  $\rho$  are fluid properties defined previously and evaluated at the mean temperature of the fluid.

The selection of the appropriate correlation for the heat-transfer coefficient depends on the following:

1. surface orientation—vertical or horizontal,
2. laminar or turbulent flow, and
3. for horizontal surfaces, location of the gas relative to a hot or cool surface. (A hot surface above the gas and a cool surface below the gas both produce stable temperature and density profiles in the gas that do not result in buoyancy-driven flows, and the flow remains laminar. Conversely, a hot surface below the gas or a cool surface above the gas can produce unstable density gradients that lead to buoyancy-driven flows and improved heat transfer.)

Five  $Nu$  correlations are required to describe the above situations:

Vertical surface in laminar flow [ $0.78 < (Gr \cdot Pr) < 7.6372 \cdot 10^7$ ]

$$Nu = \frac{h \cdot L}{k} = \frac{1}{3} \cdot [(f - 2.0) \cdot 0.59 \cdot (Gr \cdot Pr)^{0.25} + (5.0 - f) \cdot 1.05 \cdot (Gr \cdot Pr)^{0.2}] , \quad (\text{B26})$$

where

$$f = \min[5.0, \log_{10}(Gr \cdot Pr)]$$

Vertical surface in turbulent flow [ $7.6372 \cdot 10^7 \leq (Gr \cdot Pr) \leq 10^{13}$ ]

$$Nu = \frac{h \cdot L}{k} = 0.13 \cdot (Gr \cdot Pr)^{1/3} \quad (\text{B27})$$

Horizontal surface in laminar flow [ $1.23 < (\text{Gr} \cdot \text{Pr}) < 1.0844 \cdot 10^7$ ]

$$\text{Nu} = \frac{h \cdot L}{k} = \frac{1}{3} \cdot [(f - 2.0) \cdot 0.54 \cdot (\text{Gr} \cdot \text{Pr})^{0.25} + (5.0 - f) \cdot 0.96 \cdot (\text{Gr} \cdot \text{Pr})^{0.2}] , \quad (\text{B28})$$

where  $f$  is defined above and either the hot surface ( $T_{\text{surface}} > T_{\text{gas}}$ ) is below the gas or the cool surface ( $T_{\text{surface}} < T_{\text{gas}}$ ) is above the gas.

Horizontal surface in turbulent flow [ $1.0844 \cdot 10^7 \leq (\text{Gr} \cdot \text{Pr}) \leq 3.0 \cdot 10^{10}$ ]

$$\text{Nu} = \frac{h \cdot L}{k} = 0.14 \cdot (\text{Gr} \cdot \text{Pr})^{1/3} , \quad (\text{B29})$$

where again the hot surface ( $T_{\text{surface}} > T_{\text{gas}}$ ) is below the gas or the cool surface ( $T_{\text{surface}} < T_{\text{gas}}$ ) is above the gas.

Horizontal surface with a stable density gradient [ $39.2 < (\text{Gr} \cdot \text{Pr}) < 10^{10}$ ]

$$\text{Nu} = \frac{h \cdot L}{k} = \frac{1}{3} \cdot [(g - 2.5) \cdot 0.27 \cdot (\text{Gr} \cdot \text{Pr})^{0.25} + (5.5 - g) \cdot 0.48 \cdot (\text{Gr} \cdot \text{Pr})^{0.2}] , \quad (\text{B30})$$

where

$$g = \min[5.5, \log_{10}(\text{Gr} \cdot \text{Pr})]$$

for laminar flow when the hot surface ( $T_{\text{surface}} > T_{\text{gas}}$ ) is above the gas or the cool surface ( $T_{\text{surface}} < T_{\text{gas}}$ ) is below the gas.

Equations (B26)–(B30) are based on Ref. B8 (pages 172–175 and 180–181). Equations B26, B28, and B30 represent extensions of correlations in Ref. B8 to improve the fit to data in the same reference at lower values of  $\text{Gr} \cdot \text{Pr}$ . Application of the three laminar correlations above extended below the minimum value given for  $\text{Gr} \cdot \text{Pr}$  but was constrained by conduction through the fluid:

$$h = \max\left(\frac{\text{Nu} \cdot k}{L}, \frac{k}{\Delta x}\right) \quad (\text{B31})$$

where  $\Delta x$  is the conduction length defined in Eq. (B7) or (B8) above.

**B.2.3. Thermal Properties for PuO<sub>2</sub>.** The thermal analysis of PuO<sub>2</sub> powder requires the necessary material properties—specific heat  $c_p$ , density  $\rho$ , and thermal conductivity  $k$ . The  $c_p$ , which is only required for transient analysis, is 18.250 cal/(mole·°C) [282.0 J/(kg·K), 0.07832 W·h/(kg·K) as required by TSAP, or 0.06734 Btu/(lb<sub>m</sub>·°R)] at 400 K (126.9°C or 260.3°F).<sup>B10</sup> The density of powder varies with porosity, and the maximum or theoretical density of the solid material is required to convert powder density to porosity. The theoretical density of the solid PuO<sub>2</sub> is 11.45 g/cm<sup>3</sup> (714.8 lbm/ft<sup>3</sup>).<sup>B11</sup>

[Reference B12 gives the maximum density for PuO<sub>2</sub> as 11.46 g/cm<sup>3</sup>, which confirms the personal communication of Ref. B11.] The thermal conductivity of the powder is a function of its porosity and the thermal conductivities of the solid and gas components.

For a powder with a porosity  $\omega$  (volume occupied by the gas divided by the total volume) and consisting of unconsolidated solid particles and a fill gas with thermal conductivities  $k_s$  and  $k_g$ , respectively, Deissler and Eian<sup>B13</sup> determined the effective thermal conductivity  $k_e$  of the powder as an interpolation among the thermal conductivities of the same powder components at four known porosities:

For a solid (limiting case as  $\omega \rightarrow 0$ ):

$$k_{\text{solid}} = k_s . \quad (\text{B32})$$

For conduction across a square array of cylinders ( $\omega = 0.214$ ):

$$k_{\text{cylinder}} = k_g \cdot \left[ \frac{\frac{\pi}{2}}{\left( \frac{k_g}{k_s} - 1 \right)} - \frac{\frac{\pi}{2} - \sin^{-1} \left( \frac{k_g}{k_s} - 1 \right)}{\left( \frac{k_g}{k_s} - 1 \right) \sqrt{2 \cdot \frac{k_g}{k_s} - \left( \frac{k_g}{k_s} \right)^2}} \right] . \quad (\text{B33})$$

For conduction across a cubical array of spheres ( $w = 0.475$ ):

$$k_{\text{sphere}} = k_g \cdot \left\{ \frac{\frac{\pi}{2}}{\left( \frac{k_g}{k_s} - 1 \right)^2} \left[ \left( \frac{k_g}{k_s} - 1 \right) - \ln \frac{k_g}{k_s} \right] + 1 - \frac{\pi}{4} \right\} . \quad (\text{B34})$$

For a gas (limiting case as  $\omega \rightarrow 1$ ):

$$k_{\text{gas}} = k_g . \quad (\text{B35})$$

Reference B13 does not specify the method of interpolation among Eq. (B32)–(B35); neither does it specify a range of porosities outside of which the correlation is not valid. We used linear interpolation based on  $\omega$  to evaluate  $k_e$  at densities of interest.

Reference B14 presents the Deissler-Eian correlation in graphical form with the following limits:  $0.2 < \omega < 0.6$  and  $1 < k_s/k_g < 6000$ . For the case of temperatures above 212°F (100°C), the reference develops a term to account for particle-to-particle radiation heat transfer. We chose to ignore this term in light of perceived uncertainties in  $k_e$ .

To evaluate the above correlation for PuO<sub>2</sub> powders, we used 1.884 W/(m·K) [1.089 Btu/(h·ft·°F)] as the thermal conductivity of solid PuO<sub>2</sub>.<sup>B15</sup> This thermal conductivity actually describes sintered UO<sub>2</sub>; however, Ref. B12 indicates that in lieu of data the thermal conductivity of solid PuO<sub>2</sub> can be approximated by UO<sub>2</sub>. The value selected for the thermal conductivity may be low relative to that for maximum density PuO<sub>2</sub> (or

$\text{UO}_2$ ), but the product form to which it applies appears to be more consistent with the process by which the loose oxide is made (calcining very fine powders).

Table B-II gives the thermal conductivity of  $\text{PuO}_2$  powder based on the Deissler-Eian correlation above for selected densities of the powder and various gases. Note that we have evaluated the correlation outside of the valid range of porosities from Ref. B14.

The densities reflect the range for unconsolidated  $\text{PuO}_2$  materials in the DOE complex,<sup>B11, B16</sup> and the exact values in the table (except for 2.00 g/cm<sup>3</sup>) result from the specification of the total mass of  $\text{PuO}_2$  allowed in the convenience jar and volumes at different levels in the TSAP input model of that jar. For the analyses documented here, we used only the thermal conductivities resulting from air as the fill gas.

References B13 and B14 make the point that if the average pore size in the powder is comparable with or smaller than the mean-free path of the gas molecules, then the

thermal conductivity of the gas as applied in the correlation should be reduced. The pressure at which the average pore size and mean-free path become comparable is described as the break-away pressure  $P_b$ :

$$P_b = 1.77 \cdot 10^{-21} \cdot \frac{T^{\circ}\text{R}}{D_p \cdot d^2} , \quad (\text{B36})$$

where  $P_b$  is gas pressure in  $\text{lbf}/\text{ft}^2$ ,  $T^{\circ}\text{R}$  is absolute temperature in  $^{\circ}\text{R}$ ,  $D_p$  is the average particle size in ft, and  $d$  is the mean gas-molecule diameter in feet. Because the equation is not dimensionally homogeneous, it must be evaluated with the units indicated. This equation can be interpreted as defining a minimum average particle size below which the thermal conductivity of the gas and also the powder is reduced. Table B-III shows the minimum particle size for the storage conditions of 400 K or 720 $^{\circ}\text{R}$  (260 $^{\circ}\text{F}$  or 127 $^{\circ}\text{C}$ )

**TABLE B-II**  
**THERMAL CONDUCTIVITY OF  $\text{PuO}_2$  POWDER**

$\text{PuO}_2$ density $(\frac{\text{g}}{\text{cm}^3})$	$\text{PuO}_2$ porosity (-)	$\text{PuO}_2$ Thermal Conductivity					
		Fill Gas					
		helium		air		argon	
		$(\frac{\text{W}}{\text{m}\cdot\text{K}})$	$(\frac{\text{Btu}}{\text{h}\cdot\text{ft}\cdot{}^{\circ}\text{R}})$	$(\frac{\text{W}}{\text{m}\cdot\text{K}})$	$(\frac{\text{Btu}}{\text{h}\cdot\text{ft}\cdot{}^{\circ}\text{R}})$	$(\frac{\text{W}}{\text{m}\cdot\text{K}})$	$(\frac{\text{Btu}}{\text{h}\cdot\text{ft}\cdot{}^{\circ}\text{R}})$
2.00	0.825	0.297	0.172	0.079	0.046	0.055	0.032
2.72	0.763	0.340	0.196	0.096	0.055	0.068	0.039
3.02	0.737	0.358	0.207	0.103	0.059	0.073	0.042
4.54	0.603	0.448	0.259	0.138	0.080	0.099	0.057
6.70	0.415	0.630	0.364	0.243	0.140	0.187	0.108

**TABLE B-III**  
**MINIMUM PuO<sub>2</sub> PARTICLE SIZES BASED ON THE BREAK-AWAY PRESSURE**

Fill gas	Minimum Particle Size		
	(mm)	(microns)	(in.)
helium	0.612	612	0.0241
air	0.227	227	0.00896
argon	0.266	266	0.0105

and 78 200 Pa (11.3 psia or 1630 lbf/ft<sup>2</sup>), which is typical atmospheric pressure for Los Alamos or Rocky Flats, and for different fill gases.

Because helium has a much smaller mean molecular diameter, the particle size at which the break-away pressure criterion is met is larger than for the other gases. Although Ref. B14 provides a formula for calculating the reduced gas thermal conductivities, we chose to ignore the effect because the distributions of particle sizes in the oxide powders were not available.

As a final note on PuO<sub>2</sub> thermal conductivity, the Hadley weighted-average correlation<sup>B17</sup> also describes the thermal conductivity of unconsolidated powders:

$$k_e = k_f \cdot \left[ (1 - a_0) \cdot \frac{\omega f_0 + (1 - \omega f_0) \cdot \frac{k_s}{k_f}}{1 + \omega \cdot (1 - f_0) \cdot \left( \frac{k_s}{k_f} - 1 \right)} + a_0 \cdot \frac{2 \cdot (1 - \omega) \cdot \left( \frac{k_s}{k_f} \right)^2 + (1 + 2\omega) \cdot \frac{k_s}{k_f}}{(2 + \omega) \cdot \frac{k_s}{k_f} + 1 - \omega} \right], \quad (B37)$$

where  $k_e$ ,  $k_f$ ,  $k_s$ , and  $\omega$  are defined as before,  $f_0$  is a periodic structure function, and  $a_0$  is the weighting function. The  $f_0$  and  $a_0$  are defined as

$$f_0 = 0.8 + 0.1 \cdot \omega ,$$

and

$$\log(a_0) = \begin{cases} -4.898 \cdot \omega & \text{for } 0 \leq \omega \leq 0.0827 ; \\ -0.405 - 3.154 \cdot (\omega - 0.0827) & \text{for } 0.0827 \leq \omega \leq 0.298 ; \\ -1.084 - 6.778 \cdot (\omega - 0.298) & \text{for } 0.298 \leq \omega \leq 0.580 . \end{cases}$$

As indicated in the definition of  $a_0$ , the Hadley correlation is limited to  $\omega \leq 0.58$ , but only the highest-density oxide in our analyses has a porosity inside this range. Therefore, we have applied the correlation outside its stated range of validity to cover the full range of oxide densities. Table B-IV compares the Hadley correlation to Deissler-Eian correlation for  $\text{PuO}_2$  powders with air as the fill gas. The Hadley correlation produces thermal conductivities that are slightly higher than those from Deissler-Eian; as indicated previously, we have used the Deissler-Eian values.

### B.3. TSAP Input Models

Figure B1 shows the input node diagram that describes the BNFL outer and inner containers, the Vollrath convenience jar, the plutonium ingot, and the various gas spaces inside the containers. The left edge of the diagram is the centerline of the container assembly. To show the node numbers for thin container walls and narrow gaps filled with gas, we have not drawn the figure to scale; the distortion is particularly evident in the gaps between the Vollrath and inner BNFL container.

The BNFL outer and inner containers are made of 316 stainless steel, and the Vollrath jar is fabricated from 304 stainless steel. Because the container walls are generally thin and because the thermal conductivity for stainless steel is large relative to gas, we generally ignored the thermal resistance associated with heat flow across the walls. An estimate of the total temperature drop across the thin walls where we invoked this approximation is  $<0.1^\circ\text{C}$  ( $0.18^\circ\text{F}$ ). Conduction paths are defined between all adjacent metal nodes, and enhanced conduction is specified between all adjacent gas-filled nodes. In the relatively open gas regions between the ingot and the inside surface of the Vollrath and between the tops of the Vollrath and the inner container, we used the user-FORTRAN feature in TSAP to calculate the heat-transfer coefficients from correlations with the constraint that the code uses the maximum conductance based on either the Nu number or the thermal conductivity as defined by Eq. (B31); for helium fill gas, the conduction limit applied in almost all cases. Across the more narrow gaps, we assumed

**TABLE B-IV**  
**THERMAL CONDUCTIVITY OF  $\text{PuO}_2$  POWDER IN AIR**  
**FROM TWO DIFFERENT CORRELATIONS**

$\text{PuO}_2$ density $(\frac{\text{g}}{\text{cm}^3})$	$\text{PuO}_2$ porosity (-)	<u><math>\text{PuO}_2</math> Thermal Conductivity</u>				% Difference (-)
		Correlation		<u>Deissler-Eian</u>	<u>Hadley</u>	
		$(\frac{\text{W}}{\text{m}\cdot\text{K}})$	$(\frac{\text{Btu}}{\text{h}\cdot\text{ft}\cdot^\circ\text{R}})$	$(\frac{\text{W}}{\text{m}\cdot\text{K}})$	$(\frac{\text{Btu}}{\text{h}\cdot\text{ft}\cdot^\circ\text{R}})$	
2.00	0.825	0.079	0.046	0.083	0.048	5.2
2.72	0.763	0.096	0.055	0.103	0.060	7.6
3.02	0.737	0.103	0.059	0.112	0.064	8.7
4.54	0.603	0.138	0.080	0.162	0.093	17.3
6.70	0.415	0.243	0.140	0.273	0.158	12.6

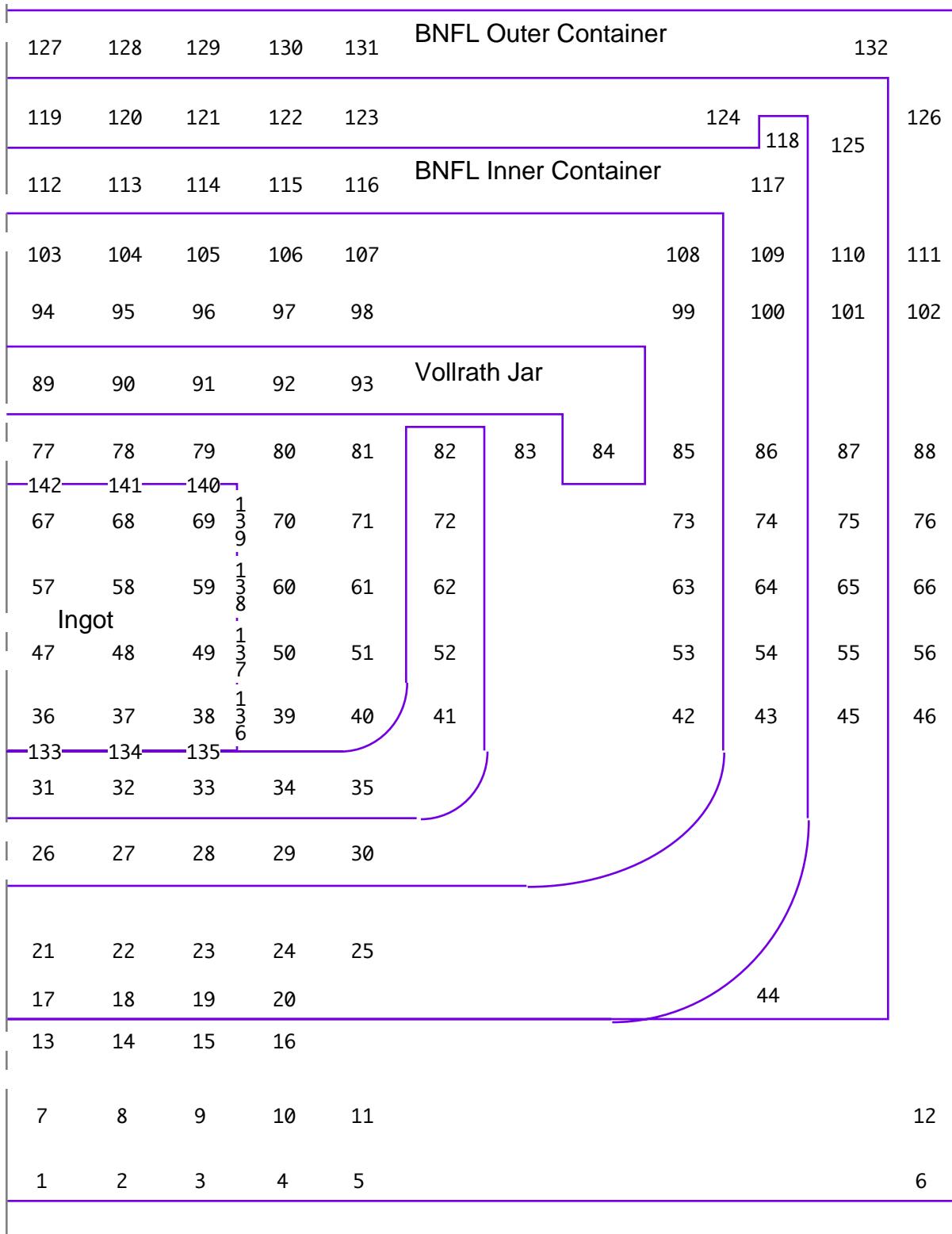


Fig. B1. TSAP node diagram for the BNFL outer and inner containers and the Vollrath jar with the plutonium ingot.

that the convection was conduction limited and modeled the path as conduction with the thermal conductivity of the gas. Radiation heat-transfer paths have been defined across all gas-filled regions.

For thicker walls, in particular the bottom of the inner and outer containers, and for the ingot, we defined surface nodes to capture the  $\Delta T$  between the node center and the surface. Nodes 133–142 define the surface of the ingot, and a contact resistance is modeled between the bottom face of the ingot and the bottom of the Vollrath jar. Similarly, surface nodes 13–16 in the outer container and 17–20 in the inner container allow the representation of contact resistances between the two containers. Surface nodes 1–6 define the lower surface of the outer container and provide for adding contact resistances when the container is placed on the plate or in the drum. Reference B2 (Table 2-2, p. 50) provides the basis for specifying the contact resistances.

The line contact between the Vollrath and the BNFL inner container has been averaged over gas nodes 30 and 42 to provide a narrow gas gap separating the two containers. This modeling results in no metal-to-metal conduction path, which is consistent with the idealized container geometry that results in a zero area for the contact. Radiation heat transfer is present between the corner nodes 35 and 41 of the Vollrath and the corner nodes 25 and 43 of the BNFL inner container.

Figure B2 shows the changes to the node structure inside the Vollrath jar to accommodate the two plutonium buttons. The node structure for the Vollrath itself, the BNFL inner and outer containers, and the intervening gas regions are the same as shown in Fig. B1. Both buttons are lined with surface nodes to define the temperature drops from the interior of the buttons to the surface and to define better the wall temperatures required for calculating the convective heat transfer at the surface.

The figure indicates that there are no metal-to-metal conduction paths between the two buttons and between the lower button and the bottom of the Vollrath. Instead, there are very narrow gas nodes (36 and 47) for which we have averaged the actual gas volumes over the areas of the nodes. Because the path length through the two gas nodes is very small, the heat transfer is modeled as conduction through the gas and radiation heat transfer between the solid surfaces involved.

Figure B3 shows the node diagram that represents the BNFL outer and inner containers and the BNFL convenience jar containing  $\text{PuO}_2$  powder. The node structure is qualitatively similar to that in Fig. B1 except that there is no gap between the bottoms of the convenience jar and the inner container. Also, there are more nodes inside the convenience jar and in the side walls of the containers. In this case, all three containers are made from 316 stainless steel. The location of the oxide inside the convenience jar is a function of the oxide density, as shown in Table B-V. We have defined sufficient surface nodes (56–70) to have surface nodes at the free surface of the oxide for the

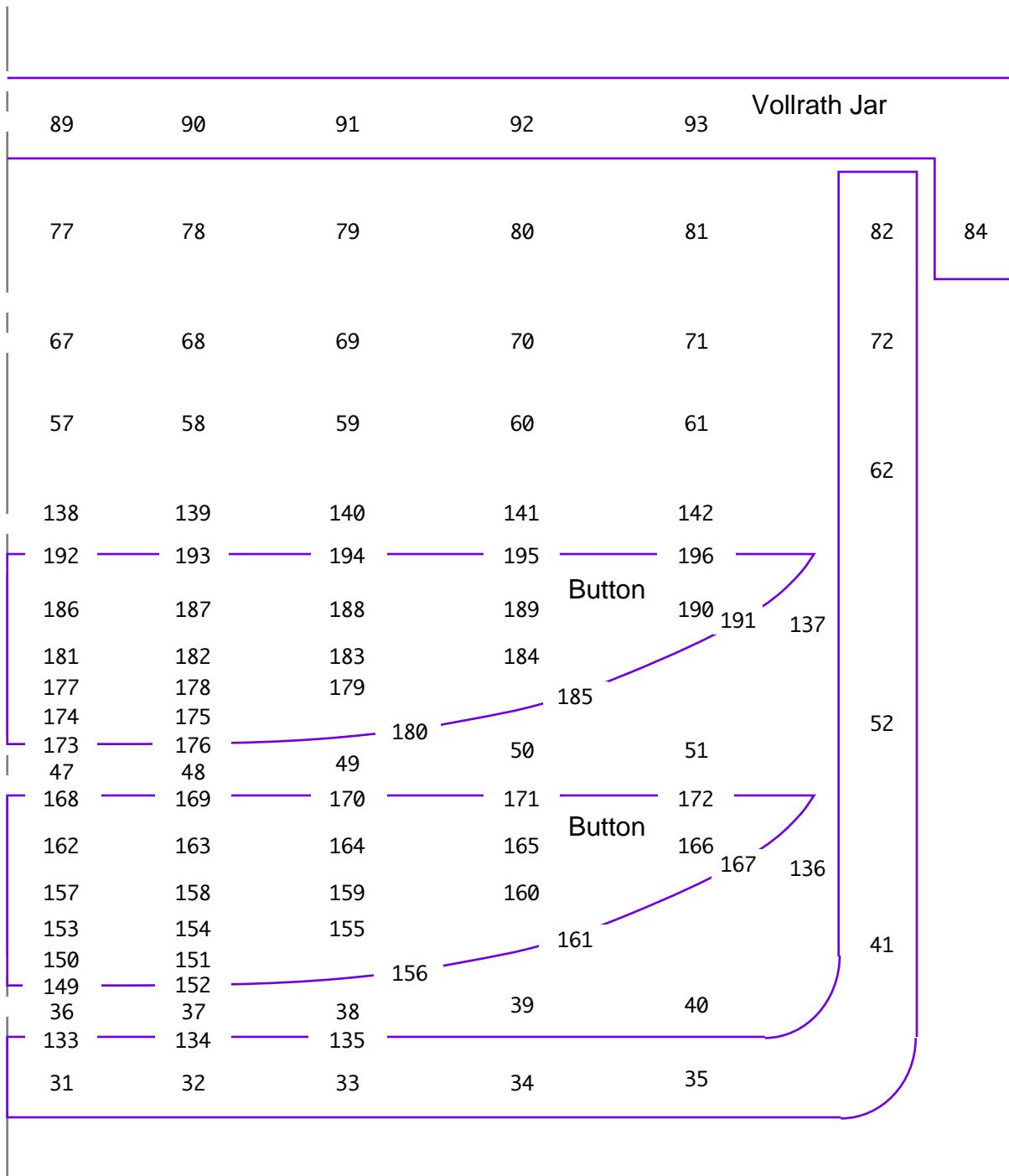


Fig. B2. TSAP node diagram for the Vollrath jar with the two plutonium buttons.

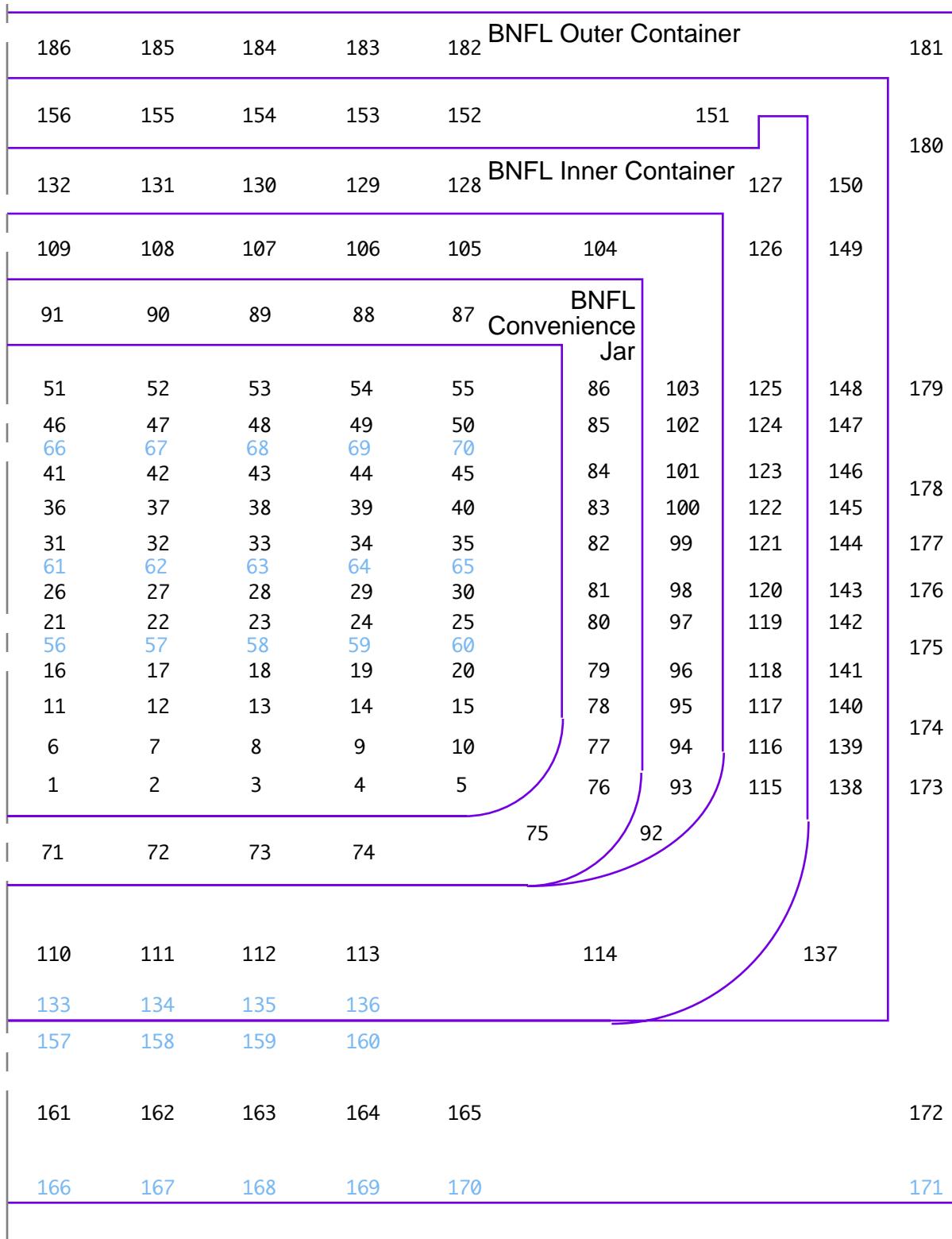


Fig. B3. TSAP node diagram for the BNFL outer and inner containers and convenience jar for PuO<sub>2</sub>.

**TABLE B-V**  
**NODES REPRESENTING THE PuO<sub>2</sub> POWDER**

PuO <sub>2</sub> density (g/cm <sup>3</sup> )	PuO <sub>2</sub> porosity (-)	PuO <sub>2</sub> Node Numbers		
		Volume Nodes	Surface Nodes	Imbedded Free Surface
2.00	0.825	1-55	56-70	
2.72	0.763	1-55	56-70	
3.02	0.737	1-45	56-65	66-70
4.54	0.603	1-30	56-60	61-65
6.70	0.415	1-20		56-60

densities represented. Depending on the oxide density, these surface nodes may lie on the free surface of the oxide, be inside the oxide, or be in the gas space.

Figure B4 shows the dimensions for the storage drum used at Rocky Flats. The drum and its internal fixture are manufactured from mild-carbon steel. The nodes are also shown; the node numbers apply to the TSAP model of for the ingot. For the model with the two buttons, the node numbers were incremented by a constant value because more nodes were used inside the Vollrath to represent the two buttons and the gas space. This model of the drum is axially symmetric.

Figure B5 shows the dimensions of the cabinet model and the node numbers that apply to the BNFL container assembly with the plutonium ingot. The cabinet is manufactured from 304 stainless steel. This model is a very coarse three-dimensional model in that the surfaces at the front and back of the cabinet are different. The cabinet model is based on information contained in Ref. B18. The actual cabinet includes three shelves, each of which can hold two or four drums; we chose to work with the version for four drums/shelf. The worst case location for a cabinet within the vault appears to be in a row with identical cabinets on each side and behind. This representation results in the back surface of the model being an adiabatic boundary. Choosing a middle container on the middle shelf permitted us to assume that there are adiabatic boundaries to each side of and behind the selected drum. The cabinet shelves above and below the selected drum are periodic boundaries in that heat transfer into one shelf comes out of the other shelf. It is not clear from the drawings of the cabinet if the openings in the cabinet at the bottom and top are sufficient to develop natural circulation flow through the cabinet. The base case cabinet model was set up with 85°F (29.4°C) air as a boundary condition (heat sink) inside the cabinet to represent natural circulation, and a sensitivity calculation was run to determine the effect of this assumption. Heat removal from the cabinet is through the front surface to the outside air and to the air inside the cabinet for the base case. The sensitivity case assumed no natural circulation flow through the cabinet and removed the fixed air temperature inside the cabinet to allow the air temperature to adjust based on the heat-transfer coupling. For the sensitivity case, all heat removal is through the front of the cabinet to the outside air at 80°F (26.7°C).

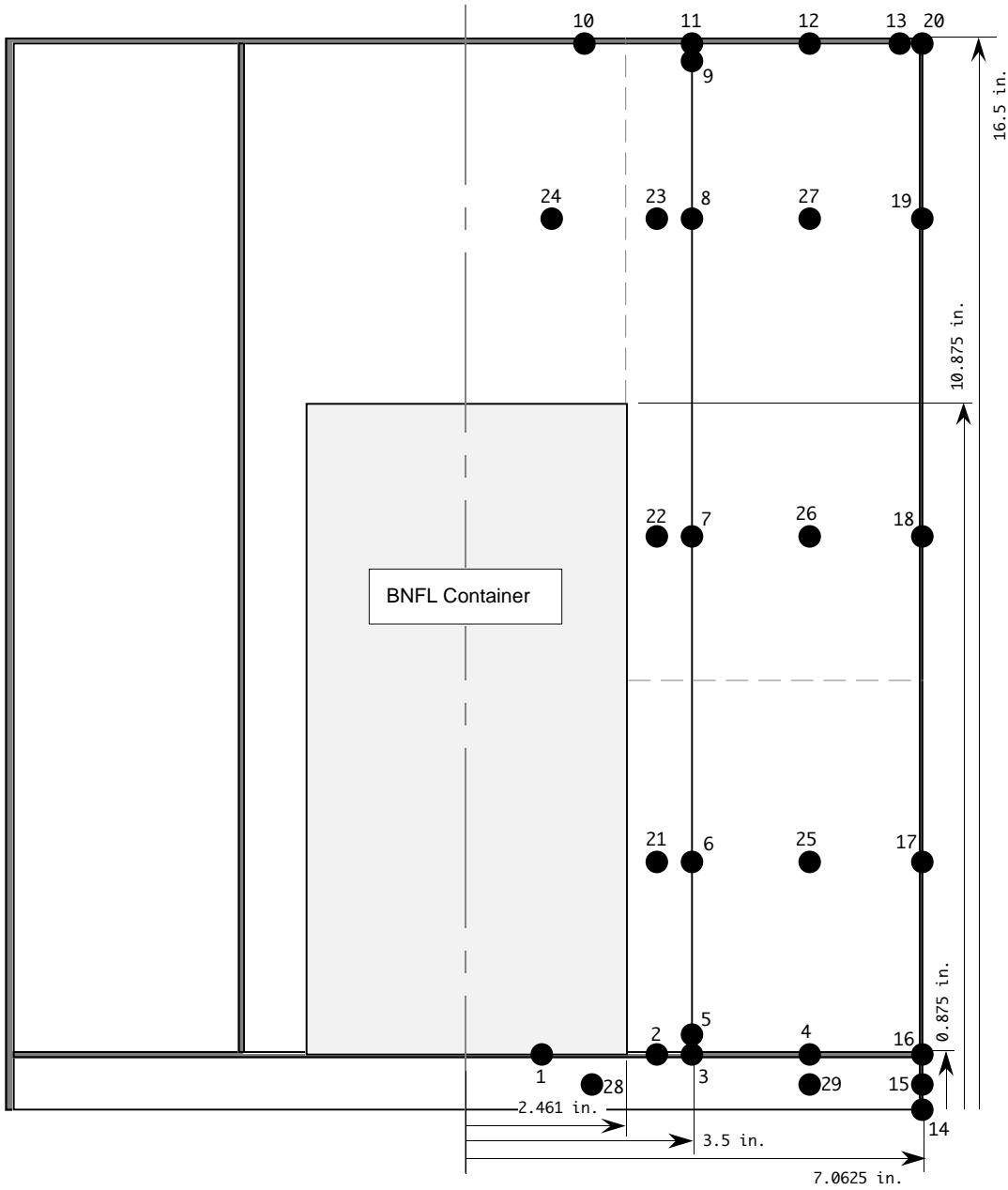


Fig. B4. TSAP node diagram for the Rocky Flats storage drum with the BNFL container assembly and plutonium ingot.

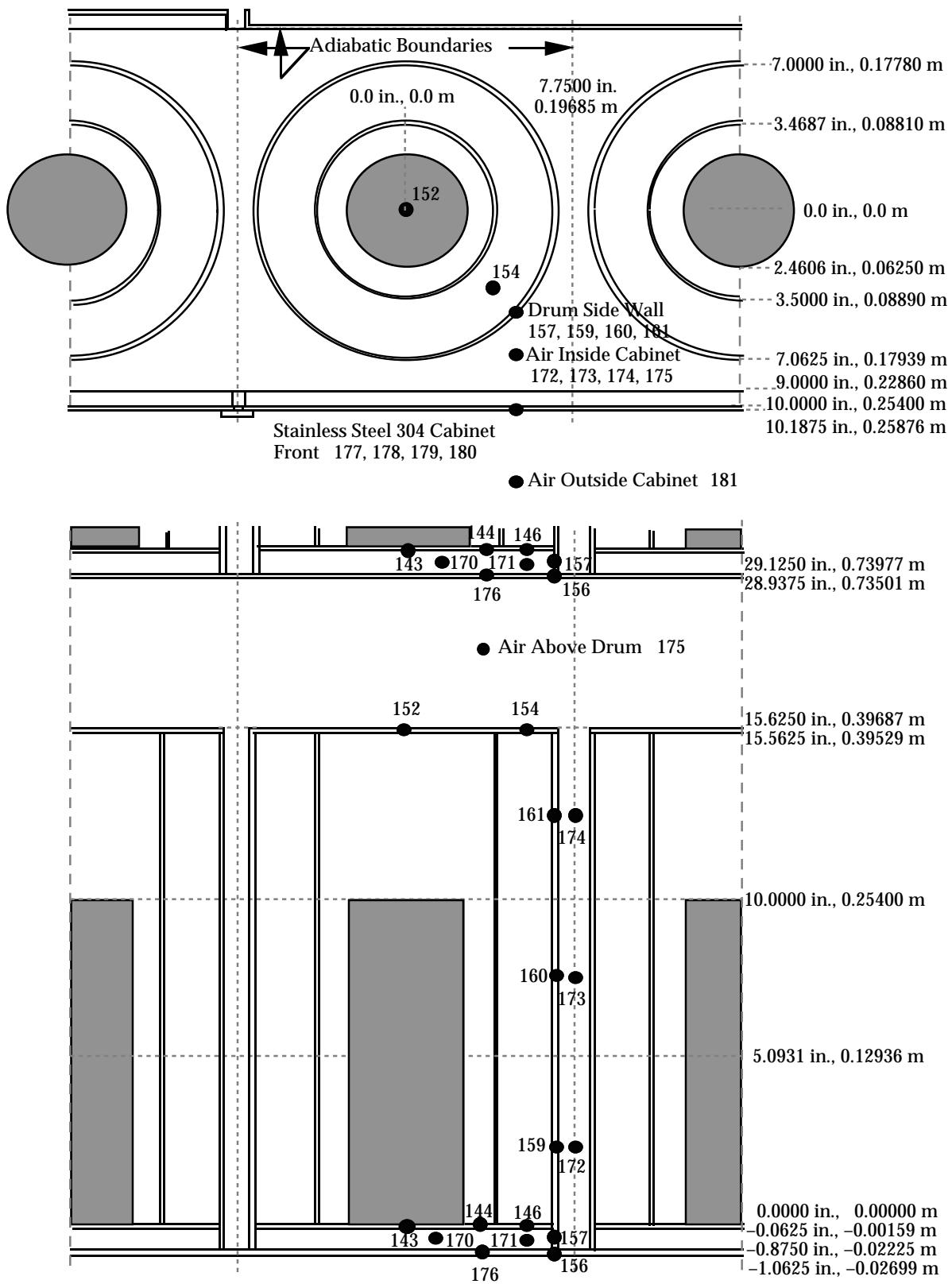


Fig. B5. TSAP node diagram for the Rocky Flats storage cabinet with the storage drum (top and side views).

Appendix C contains a listing of the input deck for the case of a metal ingot with the container assembly placed inside a storage drum, a combination of Figs. B1 and B4. Appendix D is a listing of the input for the case of two metal buttons with the container and drum assembly placed inside the cabinet, a combination of Figs. B1, B2, B4, and B5. Appendix E is a listing of the input for the case of 4.5-g/cm<sup>3</sup> oxide with a specific power of 3.01 W/kg (total power of 15.0 W) with the container assembly sitting on a flat plate, a combination of Fig. B3 and a simple model of the stainless-steel plate. These three appendices present the input decks as they were used except that comment lines, which don't affect the calculation, have been truncated to 78 characters or less to prevent wrapping of the text. Also, the title line, line 1, of the oxide deck in Appendix E has been truncated similarly.

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## APPENDIX C

### TSAP INPUT DECK FOR PLUTONIUM-METAL INGOT—DRUM CASE

```
BNFL Container with Vollrath - in a drum in air
NODE DMOD
COMM
COMM Initial Condition: T = 2.6667E+01 C
COMM
COMM Total Power = 15 W
COMM Pu mass = 4.4 kg
COMM Power den = 3.40909091 W/kg
COMM
COMM Material Properties
COMM          cp           rho         k        emissivity
COMM          (W.h/kg.K)   (kg/m^3)    (W/m.K)   (-)
COMM Pu metal     3.9400E-02  1.9860E+04  6.5000E+00  5.0000E-01
COMM Pu - He mix  3.5028E-01  1.5466E+04  5.0957E+00  3.8937E-01
COMM SS 304       1.3442E-01  8.0243E+03  1.5130E+01  3.0000E-01
COMM SS 316       1.3119E-01  7.9620E+03  1.3650E+01  3.0000E-01
COMM He           1.4444E+00  1.2100E-01  1.5340E-01
COMM Air          2.7972E-01  9.0880E-01  2.5810E-02
COMM
COMM k(Pu metal) = 6.15856 + 2.11264E-02*TC + 2.0E-05*TC**2
COMM                 = 6.5000E+00 W/m.K for TC = 15.92 C (60.66 F)
COMM k(He gas)    = 3.3366E-03*(TC+273.16)**0.668
COMM                 = 1.5340E-01 W/m.K for TC = 35.02 C (95.04 F)
COMM
COMM Enhancement Factors - conduction represents convection
COMM                                     Enhancement Factor
COMM Vollrath                10
COMM BNFL Inner (open regions only) 5
COMM BNFL Outer (open regions only) 5
COMM Drum                   5
COMM Cabinet Side            10
COMM Cabinet Top              2
COMM Bulk Air                 1000
COMM
COMM Heat Transfer Coefficients (at 78.2 kPa)
COMM                                     htc (W/m^2.K)
COMM Inside container             conduction limited
COMM Container, outside, vertical surface 2.20
COMM Container, outside, top      2.47
COMM Container, outside, bottom   1.47
COMM Drum, vertical surfaces     1.65
COMM Drum, inside, top surface   1.90
COMM Drum, inside, bottom surface 0.96
COMM Drum, outside, top surface  1.90
COMM Drum, outside, bottom surface 0.96
COMM Cabinet walls, vertical    1.41
COMM Cabinet, inside top         1.84
COMM Cabinet, inside bottom      0.62
COMM
COMM Contact HTCs (W/m^2.K) -- resistance = 1/HTC
COMM
COMM Vollrath side to lid (c84) 1892.8
COMM                               Ring 1 Ring 2 Ring 3 Ring 4 Ring 5 Ring 6
```

COMM Pu to Vollrath (c29-31) 1892.8 1892.8 1892.8  
 COMM BNFL in to out (c11-14) 1892.8 1892.8 1892.8 1892.8  
 COMM BNFL outb to ??? (n1-6) 1892.8 1892.8 1892.8 1892.8 1892.8 1892.8  
 COMM  
 COMM Radiation Heat Transfer  
 COMM Eff.Emissivity  
 COMM Pu & SS304 0.23077  
 COMM SS304 & SS304 0.17647  
 COMM SS304 & SS316 0.17647  
 COMM SS316 & SS316 0.17647  
 COMM  
 COMM N#, TEMP, SP.HEAT, DENSITY, VOLUME, POWER  
 COMM , (C), (W.h/kg.K), (kg/m^3), (m^3), (W)  
 0001,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0002,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0003,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
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 0063,2.6667E+01,1.4444E+00,1.2100E-01,6.5452E-05,0.0000E+00  
 0064,2.6667E+01,1.3119E-01,7.9620E+03,2.2533E-05,0.0000E+00  
 0065,2.6667E+01,1.4444E+00,1.2100E-01,1.5347E-05,0.0000E+00  
 0066,2.6667E+01,1.3119E-01,7.9620E+03,4.7603E-05,0.0000E+00  
 0067,2.6667E+01,3.9400E-02,1.9860E+04,1.0131E-06,6.8590E-02  
 0068,2.6667E+01,3.9400E-02,1.9860E+04,8.1046E-06,5.4872E-01  
 0069,2.6667E+01,3.9400E-02,1.9860E+04,1.6209E-05,1.0974E+00  
 0070,2.6667E+01,1.4444E+00,1.2100E-01,3.3913E-05,0.0000E+00  
 0071,2.6667E+01,1.4444E+00,1.2100E-01,6.6683E-05,0.0000E+00  
 0072,2.6667E+01,1.3442E-01,8.0243E+03,4.7760E-06,0.0000E+00  
 0073,2.6667E+01,1.4444E+00,1.2100E-01,2.0801E-05,0.0000E+00  
 0074,2.6667E+01,1.3119E-01,7.9620E+03,9.0155E-06,0.0000E+00  
 0075,2.6667E+01,1.4444E+00,1.2100E-01,6.1404E-06,0.0000E+00  
 0076,2.6667E+01,1.3119E-01,7.9620E+03,1.9046E-05,0.0000E+00  
 0077,2.6667E+01,1.4444E+00,1.2100E-01,1.7408E-06,0.0000E+00  
 0078,2.6667E+01,1.4444E+00,1.2100E-01,1.3927E-05,0.0000E+00  
 0079,2.6667E+01,1.4444E+00,1.2100E-01,2.7853E-05,0.0000E+00  
 0080,2.6667E+01,1.4444E+00,1.2100E-01,5.2147E-05,0.0000E+00  
 0081,2.6667E+01,1.4444E+00,1.2100E-01,7.7752E-05,0.0000E+00  
 0082,2.6667E+01,1.3442E-01,8.0243E+03,4.2316E-06,0.0000E+00  
 0083,2.6667E+01,1.4444E+00,1.2100E-01,3.1753E-06,0.0000E+00  
 0084,2.6667E+01,1.3442E-01,8.0243E+03,3.9571E-06,0.0000E+00  
 0085,2.6667E+01,1.4444E+00,1.2100E-01,2.2564E-05,0.0000E+00  
 0086,2.6667E+01,1.3119E-01,7.9620E+03,1.0396E-05,0.0000E+00  
 0087,2.6667E+01,1.4444E+00,1.2100E-01,7.0805E-06,0.0000E+00  
 0088,2.6667E+01,1.3119E-01,7.9620E+03,2.1962E-05,0.0000E+00  
 0089,2.6667E+01,1.3442E-01,8.0243E+03,4.7124E-08,0.0000E+00  
 0090,2.6667E+01,1.3442E-01,8.0243E+03,3.7699E-07,0.0000E+00  
 0091,2.6667E+01,1.3442E-01,8.0243E+03,7.5398E-07,0.0000E+00  
 0092,2.6667E+01,1.3442E-01,8.0243E+03,1.4726E-06,0.0000E+00  
 0093,2.6667E+01,1.3442E-01,8.0243E+03,2.5249E-06,0.0000E+00  
 0094,2.6667E+01,1.4444E+00,1.2100E-01,3.2465E-06,0.0000E+00  
 0095,2.6667E+01,1.4444E+00,1.2100E-01,2.5972E-05,0.0000E+00  
 0096,2.6667E+01,1.4444E+00,1.2100E-01,5.1944E-05,0.0000E+00  
 0097,2.6667E+01,1.4444E+00,1.2100E-01,1.0145E-04,0.0000E+00  
 0098,2.6667E+01,1.4444E+00,1.2100E-01,1.7395E-04,0.0000E+00  
 0099,2.6667E+01,1.4444E+00,1.2100E-01,6.5351E-05,0.0000E+00  
 0100,2.6667E+01,1.3119E-01,7.9620E+03,2.2498E-05,0.0000E+00  
 0101,2.6667E+01,1.4444E+00,1.2100E-01,1.5324E-05,0.0000E+00  
 0102,2.6667E+01,1.3119E-01,7.9620E+03,4.7529E-05,0.0000E+00  
 0103,2.6667E+01,1.4444E+00,1.2100E-01,3.2358E-06,0.0000E+00

0104,2.6667E+01,1.4444E+00,1.2100E-01,2.5887E-05,0.0000E+00  
 0105,2.6667E+01,1.4444E+00,1.2100E-01,5.1773E-05,0.0000E+00  
 0106,2.6667E+01,1.4444E+00,1.2100E-01,1.0112E-04,0.0000E+00  
 0107,2.6667E+01,1.4444E+00,1.2100E-01,1.7338E-04,0.0000E+00  
 0108,2.6667E+01,1.4444E+00,1.2100E-01,6.5136E-05,0.0000E+00  
 0109,2.6667E+01,1.3119E-01,7.9620E+03,2.2424E-05,0.0000E+00  
 0110,2.6667E+01,1.4444E+00,1.2100E-01,1.5273E-05,0.0000E+00  
 0111,2.6667E+01,1.3119E-01,7.9620E+03,4.7373E-05,0.0000E+00  
 0112,2.6667E+01,1.3119E-01,7.9620E+03,1.1781E-07,0.0000E+00  
 0113,2.6667E+01,1.3119E-01,7.9620E+03,9.4248E-07,0.0000E+00  
 0114,2.6667E+01,1.3119E-01,7.9620E+03,1.8850E-06,0.0000E+00  
 0115,2.6667E+01,1.3119E-01,7.9620E+03,3.6816E-06,0.0000E+00  
 0116,2.6667E+01,1.3119E-01,7.9620E+03,6.3123E-06,0.0000E+00  
 0117,2.6667E+01,1.3119E-01,7.9620E+03,3.1879E-06,0.0000E+00  
 0118,2.6667E+01,1.3119E-01,7.9620E+03,8.0582E-06,0.0000E+00  
 0119,2.6667E+01,1.4444E+00,1.2100E-01,9.0321E-07,0.0000E+00  
 0120,2.6667E+01,1.4444E+00,1.2100E-01,7.2257E-06,0.0000E+00  
 0121,2.6667E+01,1.4444E+00,1.2100E-01,1.4451E-05,0.0000E+00  
 0122,2.6667E+01,1.4444E+00,1.2100E-01,2.8225E-05,0.0000E+00  
 0123,2.6667E+01,1.4444E+00,1.2100E-01,4.8394E-05,0.0000E+00  
 0124,2.6667E+01,1.4444E+00,1.2100E-01,1.7865E-05,0.0000E+00  
 0125,2.6667E+01,1.4444E+00,1.2100E-01,3.3364E-06,0.0000E+00  
 0126,2.6667E+01,1.3119E-01,7.9620E+03,1.4948E-05,0.0000E+00  
 0127,2.6667E+01,1.3119E-01,7.9620E+03,7.8540E-07,0.0000E+00  
 0128,2.6667E+01,1.3119E-01,7.9620E+03,6.2832E-06,0.0000E+00  
 0129,2.6667E+01,1.3119E-01,7.9620E+03,1.2566E-05,0.0000E+00  
 0130,2.6667E+01,1.3119E-01,7.9620E+03,2.4544E-05,0.0000E+00  
 0131,2.6667E+01,1.3119E-01,7.9620E+03,4.2082E-05,0.0000E+00  
 0132,2.6667E+01,1.3119E-01,7.9620E+03,3.6458E-05,0.0000E+00  
 0133,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0134,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0135,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0136,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0137,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0138,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0139,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0140,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0141,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0142,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

COMM

COMM Totals = 0.0031163, 14.999982

COMM

COMM Initial Condition: T = 26.667 C

COMM

COMM Material Properties

COMM	cp	rho	k	emissivity
	(W.h/kg.K)	(kg/m^3)	(W/m.K)	(-)
COMM SS 316	1.3119E-01	7.9620E+03	1.3650E+01	3.0000E-01
COMM Mild CS	1.2506E-01	7.8530E+03	5.1510E+01	3.0000E-01 ...
COMM Red Paint				4.5000E-01 ...
COMM Black Lacquer				8.8000E-01 ...
COMM Concrete				6.3000E-01 ...
COMM White Paint				9.0000E-01 ...
COMM				...
COMM Air	2.7972E-01	9.0880E-01	2.5810E-02	
COMM				
COMM Enhancement Factors - conduction represents convection				
COMM				Enhancement Factor

COMM Vollrath 10  
 COMM BNFL Inner (open regions only) 5  
 COMM BNFL Outer (open regions only) 5  
 COMM Drum 5  
 COMM Cabinet, side 10  
 COMM Cabinet, top 2  
 COMM Bulk Air 1000  
 COMM  
 COMM Heat Transfer Coefficients (at 78.2 kPa)  
 COMM htc (W/m^2.K)  
 COMM Inside container conduction limited  
 COMM Container, outside, vertical surface 3.58 revised to a DT=14 K  
 COMM Container, outside, top 3.70 revised to a DT=10 K  
 COMM Container, outside, bottom 1.47  
 COMM Drum, vertical surfaces 1.65  
 COMM Drum bottom - top surface 1.90  
 COMM Drum bottom - bottom surface 0.96  
 COMM Drum top - top surface 1.90  
 COMM Drum top - bottom surface 1.90  
 COMM Cabinet walls, vertical 1.41  
 COMM Cabinet, inside top 1.84  
 COMM Cabinet, inside bottom 0.62  
 COMM  
 COMM Contact HTCs (W/m^2.K) -- resistance = 1/HTC  
 COMM  
 COMM Drum inner cylinder to drum top/bottom 1892.75 conductors 524 and 525  
 COMM Drum top to drum side 1892.75 conductor 526  
 COMM Drum bottom edge to ? 1892.75 node 156 to ???  
 COMM Ring 1 Ring 2 Ring 3 Ring 4 Ring 5 ...  
 COMM BNFL outer bottom to drum 1892.75 1892.75 1892.75 1892.75 1892.75 ...  
 COMM (conductors 461-466)  
 COMM Radii (in) Radii (m) ...  
 COMM Radiation Heat Transfer  
 COMM Effective Emissivity 2.46062992 0.0625 ...  
 COMM SS 316 & Mild CS 1.7647E-01 3.5 0.0889 ...  
 COMM SS 316 & Red Paint 2.1951E-01 7 0.1778 ...  
 COMM Mild CS & Red Paint 2.1951E-01 7.0625 0.1793875 ...  
 COMM Red Paint/Red Paint 2.9032E-01 ...  
 COMM Mild CS & Mild CS 1.7647E-01 ...  
 COMM Black Lacquer/Black Lacquer 7.8571E-01 ...  
 COMM Black Lacquer/White Paint 8.0162E-01 ...  
 COMM Black Lacquer/Concrete 5.8016E-01 ...  
 COMM  
 COMM  
 COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM (C) ,(W.h/kg.K) , (kg/m^3) , (m^3) , (W)  
 0143,2.6667E+01,1.2506E-01,7.8530E+03,1.9482E-05,0.0000E+00  
 0144,2.6667E+01,1.2506E-01,7.8530E+03,1.9934E-05,0.0000E+00  
 0145,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0146,2.6667E+01,1.2506E-01,7.8530E+03,1.1825E-04,0.0000E+00  
 0147,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0148,2.6667E+01,1.2506E-01,7.8530E+03,5.7100E-05,0.0000E+00  
 0149,2.6667E+01,1.2506E-01,7.8530E+03,5.5013E-05,0.0000E+00  
 0150,2.6667E+01,1.2506E-01,7.8530E+03,6.2363E-05,0.0000E+00  
 0151,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0152,2.6667E+01,1.2506E-01,7.8530E+03,3.9416E-05,0.0000E+00  
 0153,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0154,2.6667E+01,1.2506E-01,7.8530E+03,1.1825E-04,0.0000E+00

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0155,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0156,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0157,2.6667E+01,1.2506E-01,7.8530E+03,3.9591E-05,0.0000E+00
0158,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0159,2.6667E+01,1.2506E-01,7.8530E+03,2.3045E-04,0.0000E+00
0160,2.6667E+01,1.2506E-01,7.8530E+03,2.2203E-04,0.0000E+00
0161,2.6667E+01,1.2506E-01,7.8530E+03,2.5452E-04,0.0000E+00
0162,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0163,2.6667E+01,2.7972E-01,9.0880E-01,1.5673E-03,0.0000E+00
0164,2.6667E+01,2.7972E-01,9.0880E-01,1.5100E-03,0.0000E+00
0165,2.6667E+01,2.7972E-01,9.0880E-01,1.7118E-03,0.0000E+00
0166,2.6667E+01,2.7972E-01,9.0880E-01,1.7339E-03,0.0000E+00
0167,2.6667E+01,2.7972E-01,9.0880E-01,9.6358E-03,0.0000E+00
0168,2.6667E+01,2.7972E-01,9.0880E-01,9.2836E-03,0.0000E+00
0169,2.6667E+01,2.7972E-01,9.0880E-01,1.0524E-02,0.0000E+00
0170,2.6667E+01,2.7972E-01,9.0880E-01,5.1240E-04,0.0000E+00
0171,2.6667E+01,2.7972E-01,9.0880E-01,1.5372E-03,0.0000E+00

COMM
COMM Boundary Temperature Nodes for air calculation
COMM
-172,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
-173,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

ENDD
COND DMOD
COMM Axial conduction and convection paths for the container
COMM C#, N1, N2, K or H , AREA , DX or 1
COMM (m^2) , (m or -)
0001,0001,0007,1.3650E+01,7.8540E-05,4.5000E-03
0002,0002,0008,1.3650E+01,6.2832E-04,4.5000E-03
0003,0003,0009,1.3650E+01,1.2566E-03,4.5000E-03
0004,0004,0010,1.3650E+01,2.4544E-03,4.5000E-03
0005,0005,0011,1.3650E+01,4.2082E-03,4.5000E-03
0006,0006,0012,1.3650E+01,2.4960E-03,4.5000E-03
0007,0007,0013,1.3650E+01,7.8540E-05,4.5000E-03
0008,0008,0014,1.3650E+01,6.2832E-04,4.5000E-03
0009,0009,0015,1.3650E+01,1.2566E-03,4.5000E-03
0010,0010,0016,1.3650E+01,2.4544E-03,4.5000E-03
0011,0013,0017,1.8928E+03,7.8540E-05,1.0000E+00
0012,0014,0018,1.8928E+03,6.2832E-04,1.0000E+00
0013,0015,0019,1.8928E+03,1.2566E-03,1.0000E+00
0014,0016,0020,1.8928E+03,2.4544E-03,1.0000E+00
0015,0017,0021,1.3650E+01,7.8540E-05,7.5000E-04
0016,0018,0022,1.3650E+01,6.2832E-04,7.5000E-04
0017,0019,0023,1.3650E+01,1.2566E-03,7.5000E-04
0018,0020,0024,1.3650E+01,2.4544E-03,7.5000E-04
0019,0021,0026,1.5340E-01,7.8540E-05,7.8200E-04
0020,0022,0027,1.5340E-01,6.2832E-04,7.8200E-04
0021,0023,0028,1.5340E-01,1.2566E-03,7.8200E-04
0022,0024,0029,1.5340E-01,2.4544E-03,7.8200E-04
0023,0025,0030,1.5340E-01,3.8098E-03,2.8877E-04
0024,0026,0031,1.5340E-01,7.8540E-05,7.8200E-04
0025,0027,0032,1.5340E-01,6.2832E-04,7.8200E-04
0026,0028,0033,1.5340E-01,1.2566E-03,7.8200E-04
0027,0029,0034,1.5340E-01,2.4544E-03,7.8200E-04
0028,0030,0035,1.5340E-01,2.3089E-03,4.7648E-04
0029,0031,0133,1.8928E+03,7.8540E-05,1.0000E+00
0030,0032,0134,1.8928E+03,6.2832E-04,1.0000E+00
0031,0033,0135,1.8928E+03,1.2566E-03,1.0000E+00

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0032,0133,0036,6.5000E+00,7.8540E-05,8.5680E-03  
0033,0134,0037,6.5000E+00,6.2832E-04,8.5680E-03  
0034,0135,0038,6.5000E+00,1.2566E-03,8.5680E-03  
0035,0034,0039,1.5340E-01,2.4544E-03,8.5680E-03  
0036,0035,0040,1.5340E-01,3.2289E-03,7.9963E-03  
0037,0035,0041,1.5130E+01,2.4686E-04,1.4065E-02  
0038,0030,0042,1.5340E-01,5.5691E-04,1.4847E-02  
0039,0025,0043,1.3650E+01,4.7498E-04,1.5904E-02  
0040,0011,0044,1.5340E-01,4.2082E-03,1.0461E-03  
0041,0012,0045,1.5340E-01,7.0526E-04,2.0567E-02  
0042,0044,0025,1.5340E-01,4.6977E-03,9.3707E-04  
0043,0045,0043,1.5340E-01,5.8455E-03,2.4814E-03  
0044,0012,0046,1.3650E+01,1.3373E-03,1.5000E-02  
0045,0036,0047,6.5000E+00,7.8540E-05,2.9268E-02  
0046,0037,0048,6.5000E+00,6.2832E-04,2.9268E-02  
0047,0038,0049,6.5000E+00,1.2566E-03,2.9268E-02  
0048,0039,0050,1.5340E+00,2.4544E-03,2.9268E-02  
0049,0040,0051,1.5340E+00,3.9468E-03,2.8696E-02  
0050,0041,0052,1.5130E+01,2.6138E-04,2.8416E-02  
0051,0042,0053,1.5340E-01,1.5810E-03,2.5234E-02  
0052,0043,0054,1.3650E+01,5.4428E-04,2.8717E-02  
0053,0045,0055,1.5340E-01,3.7071E-04,3.1200E-02  
0054,0046,0056,1.3650E+01,1.1498E-03,3.1200E-02  
0055,0047,0057,6.5000E+00,7.8540E-05,4.1400E-02  
0056,0048,0058,6.5000E+00,6.2832E-04,4.1400E-02  
0057,0049,0059,6.5000E+00,1.2566E-03,4.1400E-02  
0058,0050,0060,1.5340E+00,2.4544E-03,4.1400E-02  
0059,0051,0061,1.5340E+00,3.9468E-03,4.1400E-02  
0060,0052,0062,1.5130E+01,2.6138E-04,4.1400E-02  
0061,0053,0063,1.5340E-01,1.5810E-03,4.1400E-02  
0062,0054,0064,1.3650E+01,5.4428E-04,4.1400E-02  
0063,0055,0065,1.5340E-01,3.7071E-04,4.1400E-02  
0064,0056,0066,1.3650E+01,1.1498E-03,4.1400E-02  
0065,0057,0067,6.5000E+00,7.8540E-05,2.7149E-02  
0066,0058,0068,6.5000E+00,6.2832E-04,2.7149E-02  
0067,0059,0069,6.5000E+00,1.2566E-03,2.7149E-02  
0068,0060,0070,1.5340E+00,2.4544E-03,2.7580E-02  
0069,0061,0071,1.5340E+00,3.9468E-03,2.8496E-02  
0070,0062,0072,1.5130E+01,2.6138E-04,2.8982E-02  
0071,0063,0073,1.5340E-01,1.5810E-03,2.8982E-02  
0072,0064,0074,1.3650E+01,5.4428E-04,2.8982E-02  
0073,0065,0075,1.5340E-01,3.7071E-04,2.8982E-02  
0074,0066,0076,1.3650E+01,1.1498E-03,2.8982E-02  
0075,0067,0142,6.5000E+00,7.8540E-05,6.4495E-03  
0076,0068,0141,6.5000E+00,6.2832E-04,6.4495E-03  
0077,0069,0140,6.5000E+00,1.2566E-03,6.4495E-03  
0078,0142,0077,1.5340E-01,7.8540E-05,1.1083E-02  
0079,0141,0078,1.5340E-01,6.2832E-04,1.1083E-02  
0080,0140,0079,1.5340E-01,1.2566E-03,1.1083E-02  
0081,0070,0080,1.5340E+00,2.4544E-03,1.7532E-02  
0082,0071,0081,1.5340E+00,3.9468E-03,1.7532E-02  
0083,0072,0082,1.5130E+01,2.6138E-04,1.6332E-02  
0084,0072,0084,1.8928E+03,2.0094E-04,1.0000E+00  
0085,0073,0085,1.5340E-01,1.2159E-03,1.7832E-02  
0086,0074,0086,1.3650E+01,5.4428E-04,1.7832E-02  
0087,0075,0087,1.5340E-01,3.7071E-04,1.7832E-02  
0088,0076,0088,1.3650E+01,1.1498E-03,1.7832E-02  
0089,0077,0089,1.5340E-01,7.8540E-05,1.1083E-02

0090,0078,0090,1.5340E-01,6.2832E-04,1.1083E-02  
 0091,0079,0091,1.5340E-01,1.2566E-03,1.1083E-02  
 0092,0080,0092,1.5340E-01,2.4544E-03,1.0652E-02  
 0093,0081,0093,1.5340E-01,4.2082E-03,9.7357E-03  
 0094,0084,0093,1.5130E+01,1.9754E-04,1.7300E-02  
 0095,0089,0094,1.5340E-01,7.8540E-05,2.0668E-02  
 0096,0090,0095,1.5340E-01,6.2832E-04,2.0668E-02  
 0097,0091,0096,1.5340E-01,1.2566E-03,2.0668E-02  
 0098,0092,0097,1.5340E-01,2.4544E-03,2.0668E-02  
 0099,0093,0098,1.5340E-01,4.2082E-03,2.0668E-02  
 0100,0084,0099,1.5340E-01,3.9961E-04,2.0668E-02  
 0101,0085,0099,1.5340E-01,1.1814E-03,3.0218E-02  
 0102,0086,0100,1.3650E+01,5.4428E-04,3.0218E-02  
 0103,0087,0101,1.5340E-01,3.7071E-04,3.0218E-02  
 0104,0088,0102,1.3650E+01,1.1498E-03,3.0218E-02  
 0105,0094,0103,7.6700E-01,7.8540E-05,4.1268E-02  
 0106,0095,0104,7.6700E-01,6.2832E-04,4.1268E-02  
 0107,0096,0105,7.6700E-01,1.2566E-03,4.1268E-02  
 0108,0097,0106,7.6700E-01,2.4544E-03,4.1268E-02  
 0109,0098,0107,7.6700E-01,4.2082E-03,4.1268E-02  
 0110,0099,0108,7.6700E-01,1.5810E-03,4.1268E-02  
 0111,0100,0109,1.3650E+01,5.4428E-04,4.1268E-02  
 0112,0101,0110,1.5340E-01,3.7071E-04,4.1268E-02  
 0113,0102,0111,1.3650E+01,1.1498E-03,4.1268E-02  
 0114,0103,0112,1.5340E-01,7.8540E-05,2.0600E-02  
 0115,0104,0113,1.5340E-01,6.2832E-04,2.0600E-02  
 0116,0105,0114,1.5340E-01,1.2566E-03,2.0600E-02  
 0117,0106,0115,1.5340E-01,2.4544E-03,2.0600E-02  
 0118,0107,0116,1.5340E-01,4.2082E-03,2.0600E-02  
 0119,0108,0117,1.5340E-01,1.5810E-03,2.0600E-02  
 0120,0109,0117,1.3650E+01,5.4428E-04,2.1350E-02  
 0121,0110,0125,1.5340E-01,3.7071E-04,2.5100E-02  
 0122,0111,0126,1.3650E+01,1.1498E-03,2.7100E-02  
 0123,0112,0119,1.5340E-01,7.8540E-05,5.7500E-03  
 0124,0113,0120,1.5340E-01,6.2832E-04,5.7500E-03  
 0125,0114,0121,1.5340E-01,1.2566E-03,5.7500E-03  
 0126,0115,0122,1.5340E-01,2.4544E-03,5.7500E-03  
 0127,0116,0123,1.5340E-01,4.2082E-03,5.7500E-03  
 0128,0117,0124,1.5340E-01,1.0508E-03,5.7500E-03  
 0129,0117,0118,1.3650E+01,1.0744E-03,4.5000E-03  
 0130,0118,0124,1.5340E-01,3.6898E-03,2.4209E-03  
 0131,0125,0124,1.5340E-01,3.7071E-04,6.5000E-03  
 0132,0119,0127,1.5340E-01,7.8540E-05,5.7500E-03  
 0133,0120,0128,1.5340E-01,6.2832E-04,5.7500E-03  
 0134,0121,0129,1.5340E-01,1.2566E-03,5.7500E-03  
 0135,0122,0130,1.5340E-01,2.4544E-03,5.7500E-03  
 0136,0123,0131,1.5340E-01,4.2082E-03,5.7500E-03  
 0137,0124,0132,1.5340E-01,2.4960E-03,5.7500E-03  
 0138,0126,0132,1.3650E+01,1.1498E-03,1.1500E-02

COMM

COMM Radial conduction and convection paths for the container

COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)

0139,0007,0008,1.3650E+01,2.8274E-04,5.7565E-03  
 0140,0021,0022,1.3650E+01,4.7124E-05,5.7565E-03  
 0141,0026,0027,1.5340E-01,4.9135E-05,5.7565E-03  
 0142,0031,0032,1.5130E+01,2.5133E-05,5.7565E-03  
 0143,0036,0037,6.5000E+00,5.3834E-04,5.7565E-03

0144,0047,0048,6.5000E+00,1.3006E-03,5.7565E-03  
0145,0057,0058,6.5000E+00,1.3006E-03,5.7565E-03  
0146,0067,0068,6.5000E+00,4.0523E-04,5.7565E-03  
0147,0077,0078,1.5340E+00,6.9634E-04,5.7565E-03  
0148,0089,0090,1.5130E+01,1.8850E-05,5.7565E-03  
0149,0094,0095,7.6700E-01,1.2986E-03,5.7565E-03  
0150,0103,0104,7.6700E-01,1.2943E-03,5.7565E-03  
0151,0112,0113,1.3650E+01,4.7124E-05,5.7565E-03  
0152,0119,0120,7.6700E-01,3.6128E-04,5.7565E-03  
0153,0127,0128,1.3650E+01,3.1416E-04,5.7565E-03  
0154,0008,0009,1.3650E+01,8.4823E-04,9.1783E-03  
0155,0022,0023,1.3650E+01,1.4137E-04,9.1783E-03  
0156,0027,0028,1.5340E-01,1.4740E-04,9.1783E-03  
0157,0032,0033,1.5130E+01,7.5398E-05,9.1783E-03  
0158,0037,0038,6.5000E+00,1.6150E-03,9.1783E-03  
0159,0048,0049,6.5000E+00,3.9019E-03,9.1783E-03  
0160,0058,0059,6.5000E+00,3.9019E-03,9.1783E-03  
0161,0068,0069,6.5000E+00,1.2157E-03,9.1783E-03  
0162,0078,0079,1.5340E+00,2.0890E-03,9.1783E-03  
0163,0090,0091,1.5130E+01,5.6549E-05,9.1783E-03  
0164,0095,0096,7.6700E-01,3.8958E-03,9.1783E-03  
0165,0104,0105,7.6700E-01,3.8830E-03,9.1783E-03  
0166,0113,0114,1.3650E+01,1.4137E-04,9.1783E-03  
0167,0120,0121,7.6700E-01,1.0838E-03,9.1783E-03  
0168,0128,0129,1.3650E+01,9.4248E-04,9.1783E-03  
0169,0009,0010,1.3650E+01,1.4137E-03,1.0890E-02  
0170,0023,0024,1.3650E+01,2.3562E-04,1.0890E-02  
0171,0028,0029,1.5340E-01,2.4567E-04,1.0890E-02  
0172,0033,0034,1.5130E+01,1.2566E-04,1.0890E-02  
0173,0038,0136,6.5000E+00,2.6917E-03,4.8208E-03  
0174,0136,0039,1.5340E-01,2.6917E-03,6.0688E-03  
0175,0049,0137,6.5000E+00,6.5031E-03,4.8208E-03  
0176,0137,0050,1.5340E-01,6.5031E-03,6.0688E-03  
0177,0059,0138,6.5000E+00,6.5031E-03,4.8208E-03  
0178,0138,0060,1.5340E-01,6.5031E-03,6.0688E-03  
0179,0069,0139,6.5000E+00,2.0262E-03,4.8208E-03  
0180,0139,0070,1.5340E-01,2.0262E-03,6.0688E-03  
0181,0079,0080,1.5340E+00,3.4817E-03,1.0890E-02  
0182,0091,0092,1.5130E+01,9.4248E-05,1.0890E-02  
0183,0096,0097,7.6700E-01,6.4930E-03,1.0890E-02  
0184,0105,0106,7.6700E-01,6.4717E-03,1.0890E-02  
0185,0114,0115,1.3650E+01,2.3562E-04,1.0890E-02  
0186,0121,0122,7.6700E-01,1.8064E-03,1.0890E-02  
0187,0129,0130,1.3650E+01,1.5708E-03,1.0890E-02  
0188,0010,0011,1.3650E+01,2.1206E-03,1.3405E-02  
0189,0024,0025,1.3650E+01,3.5343E-04,1.3405E-02  
0190,0029,0030,1.5340E-01,2.2525E-04,1.3405E-02  
0191,0034,0035,1.5130E+01,1.8850E-04,1.3405E-02  
0192,0039,0040,1.5340E+00,4.0160E-03,1.3026E-02  
0193,0050,0051,1.5340E+00,9.7546E-03,1.3026E-02  
0194,0060,0061,1.5340E+00,9.7546E-03,1.3026E-02  
0195,0070,0071,1.5340E+00,3.4450E-03,1.3026E-02  
0196,0080,0081,1.5340E+00,4.8167E-03,1.3026E-02  
0197,0092,0093,1.5130E+01,1.4137E-04,1.3405E-02  
0198,0097,0098,7.6700E-01,9.7396E-03,1.3405E-02  
0199,0106,0107,7.6700E-01,9.7075E-03,1.3405E-02  
0200,0115,0116,1.3650E+01,3.5343E-04,1.3405E-02  
0201,0122,0123,7.6700E-01,2.7096E-03,1.3405E-02

0202,0130,0131,1.3650E+01,2.3562E-03,1.3405E-02  
 0203,0040,0041,1.5340E-01,5.0293E-03,6.2610E-03  
 0204,0051,0052,1.5340E-01,1.3422E-02,6.9424E-03  
 0205,0061,0062,1.5340E-01,1.3422E-02,6.9424E-03  
 0206,0071,0072,1.5340E-01,5.3703E-03,6.9424E-03  
 0207,0081,0082,1.5340E-01,5.2198E-03,6.9424E-03  
 0208,0041,0042,1.5340E-01,5.0579E-03,1.2063E-03  
 0209,0052,0053,1.5340E-01,1.3630E-02,2.2972E-03  
 0210,0062,0063,1.5340E-01,1.3630E-02,2.2972E-03  
 0211,0072,0073,1.5340E-01,5.4535E-03,2.2972E-03  
 0212,0082,0083,1.5340E-01,5.3007E-03,2.9999E-04  
 0213,0083,0084,1.5340E-01,5.3614E-03,2.9999E-04  
 0214,0081,0084,1.5340E-01,7.9922E-04,7.6126E-03  
 0215,0084,0085,1.5340E-01,6.4325E-03,1.6989E-03  
 0216,0098,0099,7.6700E-01,1.3609E-02,9.6231E-03  
 0217,0107,0108,7.6700E-01,1.3565E-02,9.6231E-03  
 0218,0042,0043,1.5340E-01,5.7965E-03,1.0910E-03  
 0219,0053,0054,1.5340E-01,1.4827E-02,2.2973E-03  
 0220,0063,0064,1.5340E-01,1.4827E-02,2.2973E-03  
 0221,0073,0074,1.5340E-01,5.9323E-03,2.2973E-03  
 0222,0085,0086,1.5340E-01,6.8405E-03,1.6989E-03  
 0223,0099,0100,1.5340E-01,1.4804E-02,2.2973E-03  
 0224,0108,0109,1.5340E-01,1.4755E-02,2.2973E-03  
 0225,0116,0117,1.3650E+01,5.3721E-04,1.0370E-02  
 0226,0044,0045,1.5340E-01,2.8740E-03,6.5787E-03  
 0227,0054,0055,1.5340E-01,1.5217E-02,4.9998E-04  
 0228,0064,0065,1.5340E-01,1.5217E-02,4.9998E-04  
 0229,0074,0075,1.5340E-01,6.0884E-03,4.9998E-04  
 0230,0086,0087,1.5340E-01,7.0205E-03,4.9998E-04  
 0231,0100,0101,1.5340E-01,1.5194E-02,4.9998E-04  
 0232,0109,0110,1.5340E-01,1.5144E-02,4.9998E-04  
 0233,0117,0125,1.5340E-01,5.5135E-04,4.9998E-04  
 0234,0118,0125,1.5340E-01,3.7498E-06,4.9998E-04  
 0235,0123,0124,7.6700E-01,3.7862E-03,9.5848E-03  
 0236,0011,0012,1.3650E+01,2.9632E-03,1.2349E-02  
 0237,0045,0046,1.5340E-01,8.8281E-03,3.8220E-03  
 0238,0055,0056,1.5340E-01,1.5477E-02,4.9998E-04  
 0239,0065,0066,1.5340E-01,1.5477E-02,4.9998E-04  
 0240,0075,0076,1.5340E-01,6.1924E-03,4.9998E-04  
 0241,0087,0088,1.5340E-01,7.1405E-03,4.9998E-04  
 0242,0101,0102,1.5340E-01,1.5453E-02,4.9998E-04  
 0243,0110,0111,1.5340E-01,1.5403E-02,4.9998E-04  
 0244,0125,0126,1.5340E-01,3.3646E-03,4.9998E-04  
 0245,0124,0126,1.5340E-01,1.4954E-03,3.5408E-03  
 0246,0131,0132,1.3650E+01,3.7385E-03,1.2349E-02

COMM

COMM Radiation paths for the container

COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT  
COMM (m<sup>2</sup>) , (-)

-247,0021,0031,1.7647E-01,7.8540E-05,1.0000E+00  
 -248,0022,0032,1.7647E-01,6.2832E-04,1.0000E+00  
 -249,0023,0033,1.7647E-01,1.2566E-03,1.0000E+00  
 -250,0024,0034,1.7647E-01,2.4544E-03,1.0000E+00  
 -251,0025,0035,1.7647E-01,3.8098E-03,1.0000E+00  
 -252,0025,0011,1.7647E-01,4.6977E-03,1.0000E+00  
 -253,0043,0046,1.7647E-01,5.8455E-03,1.0000E+00  
 -254,0054,0056,1.7647E-01,1.5217E-02,1.0000E+00  
 -255,0064,0066,1.7647E-01,1.5217E-02,1.0000E+00

-256,0074,0076,1.7647E-01,6.0884E-03,1.0000E+00  
-257,0086,0088,1.7647E-01,7.0205E-03,1.0000E+00  
-258,0100,0102,1.7647E-01,1.5194E-02,1.0000E+00  
-259,0109,0111,1.7647E-01,1.5144E-02,1.0000E+00  
-260,0117,0126,1.7647E-01,5.5135E-04,1.0000E+00  
-261,0118,0126,1.7647E-01,3.7498E-06,1.0000E+00  
-262,0082,0084,1.7647E-01,5.3007E-03,1.0000E+00  
-263,0142,0082,2.3077E-01,7.8540E-05,1.5673E-01  
-264,0142,0093,2.3077E-01,7.8540E-05,1.0454E-01  
-265,0142,0092,2.3077E-01,7.8540E-05,1.8405E-01  
-266,0142,0091,2.3077E-01,7.8540E-05,2.4762E-01  
-267,0142,0090,2.3077E-01,7.8540E-05,2.6068E-01  
-268,0142,0089,2.3077E-01,7.8540E-05,4.6380E-02  
-269,0141,0082,2.3077E-01,6.2832E-04,1.6665E-01  
-270,0141,0093,2.3077E-01,6.2832E-04,1.1883E-01  
-271,0141,0092,2.3077E-01,6.2832E-04,2.1032E-01  
-272,0141,0091,2.3077E-01,6.2832E-04,2.5598E-01  
-273,0141,0090,2.3077E-01,6.2832E-04,2.1564E-01  
-274,0141,0089,2.3077E-01,6.2832E-04,3.2580E-02  
-275,0140,0082,2.3077E-01,1.2566E-03,1.9698E-01  
-276,0140,0093,2.3077E-01,1.2566E-03,1.6234E-01  
-277,0140,0092,2.3077E-01,1.2566E-03,2.6584E-01  
-278,0140,0091,2.3077E-01,1.2566E-03,2.3137E-01  
-279,0140,0090,2.3077E-01,1.2566E-03,1.2799E-01  
-280,0140,0089,2.3077E-01,1.2566E-03,1.5480E-02  
-281,0139,0052,2.3077E-01,2.0262E-03,3.5800E-02  
-282,0139,0062,2.3077E-01,2.0262E-03,3.3302E-01  
-283,0139,0072,2.3077E-01,2.0262E-03,3.2876E-01  
-284,0139,0082,2.3077E-01,2.0262E-03,2.0214E-01  
-285,0139,0093,2.3077E-01,2.0262E-03,7.5470E-02  
-286,0139,0092,2.3077E-01,2.0262E-03,2.4810E-02  
-287,0138,0041,2.3077E-01,6.5031E-03,2.1860E-02  
-288,0138,0052,2.3077E-01,6.5031E-03,1.7626E-01  
-289,0138,0062,2.3077E-01,6.5031E-03,6.0375E-01  
-290,0138,0072,2.3077E-01,6.5031E-03,1.2166E-01  
-291,0138,0082,2.3077E-01,6.5031E-03,4.7340E-02  
-292,0138,0093,2.3077E-01,6.5031E-03,2.9130E-02  
-293,0137,0034,2.3077E-01,6.5031E-03,1.8460E-02  
-294,0137,0035,2.3077E-01,6.5031E-03,5.5560E-02  
-295,0137,0041,2.3077E-01,6.5031E-03,1.2411E-01  
-296,0137,0052,2.3077E-01,6.5031E-03,6.0375E-01  
-297,0137,0062,2.3077E-01,6.5031E-03,1.7626E-01  
-298,0137,0072,2.3077E-01,6.5031E-03,1.0520E-02  
-299,0137,0082,2.3077E-01,6.5031E-03,1.1340E-02  
-300,0136,0034,2.3077E-01,2.6917E-03,2.3053E-01  
-301,0136,0035,2.3077E-01,2.6917E-03,1.0690E-01  
-302,0136,0041,2.3077E-01,2.6917E-03,3.3220E-01  
-303,0136,0052,2.3077E-01,2.6917E-03,2.9773E-01  
-304,0136,0062,2.3077E-01,2.6917E-03,3.2640E-02  
-305,0034,0041,1.7647E-01,2.4544E-03,1.8365E-01  
-306,0034,0052,1.7647E-01,2.4544E-03,3.4222E-01  
-307,0034,0062,1.7647E-01,2.4544E-03,9.5070E-02  
-308,0034,0072,1.7647E-01,2.4544E-03,1.7500E-02  
-309,0034,0082,1.7647E-01,2.4544E-03,1.3430E-02  
-310,0034,0093,1.7647E-01,2.4544E-03,3.0600E-02  
-311,0034,0092,1.7647E-01,2.4544E-03,1.6550E-02  
-312,0035,0041,1.7647E-01,7.8936E-03,4.0967E-01  
-313,0035,0052,1.7647E-01,7.8936E-03,2.4629E-01

-314,0035,0062,1.7647E-01,7.8936E-03,7.7770E-02  
-315,0035,0072,1.7647E-01,7.8936E-03,1.6220E-02  
-316,0035,0082,1.7647E-01,7.8936E-03,1.3000E-02  
-317,0035,0093,1.7647E-01,7.8936E-03,3.4630E-02  
-318,0035,0092,1.7647E-01,7.8936E-03,2.1300E-02  
-319,0041,0052,1.7647E-01,5.5557E-03,1.3798E-01  
-320,0041,0062,1.7647E-01,5.5557E-03,5.6360E-02  
-321,0041,0093,1.7647E-01,5.5557E-03,1.5090E-02  
-322,0052,0062,1.7647E-01,1.3422E-02,1.0340E-01  
-323,0052,0072,1.7647E-01,1.3422E-02,1.7520E-02  
-324,0052,0082,1.7647E-01,1.3422E-02,1.2060E-02  
-325,0052,0093,1.7647E-01,1.3422E-02,1.5710E-02  
-326,0052,0092,1.7647E-01,1.3422E-02,1.4380E-02  
-327,0062,0072,1.7647E-01,1.3422E-02,5.5590E-02  
-328,0062,0082,1.7647E-01,1.3422E-02,3.9150E-02  
-329,0062,0093,1.7647E-01,1.3422E-02,4.2100E-02  
-330,0062,0092,1.7647E-01,1.3422E-02,3.8150E-02  
-331,0062,0091,1.7647E-01,1.3422E-02,2.0070E-02  
-332,0062,0090,1.7647E-01,1.3422E-02,8.5500E-03  
-333,0072,0082,1.7647E-01,5.3703E-03,1.1280E-01  
-334,0072,0093,1.7647E-01,5.3703E-03,1.0940E-01  
-335,0072,0092,1.7647E-01,5.3703E-03,1.0100E-01  
-336,0072,0091,1.7647E-01,5.3703E-03,5.0980E-02  
-337,0072,0090,1.7647E-01,5.3703E-03,2.7230E-02  
-338,0082,0093,1.7647E-01,5.9979E-03,2.8318E-01  
-339,0082,0092,1.7647E-01,5.9979E-03,9.0350E-02  
-340,0082,0091,1.7647E-01,5.9979E-03,3.1080E-02  
-341,0082,0090,1.7647E-01,5.9979E-03,1.4370E-02  
-342,0084,0074,1.7647E-01,6.4325E-03,7.5010E-02  
-343,0084,0086,1.7647E-01,6.4325E-03,8.5000E-01  
-344,0084,0100,1.7647E-01,6.4325E-03,7.4990E-02  
-345,0072,0064,1.7647E-01,5.4535E-03,1.1177E-01  
-346,0072,0074,1.7647E-01,5.4535E-03,7.7646E-01  
-347,0072,0086,1.7647E-01,5.4535E-03,1.1177E-01  
-348,0062,0054,1.7647E-01,1.3630E-02,4.7040E-02  
-349,0062,0064,1.7647E-01,1.3630E-02,9.0593E-01  
-350,0062,0074,1.7647E-01,1.3630E-02,4.7030E-02  
-351,0052,0043,1.7647E-01,1.3630E-02,4.7030E-02  
-352,0052,0054,1.7647E-01,1.3630E-02,9.0594E-01  
-353,0052,0064,1.7647E-01,1.3630E-02,4.7030E-02  
-354,0041,0025,1.7647E-01,5.6418E-03,9.6800E-02  
-355,0041,0043,1.7647E-01,5.6418E-03,8.0688E-01  
-356,0041,0054,1.7647E-01,5.6418E-03,9.6320E-02  
-357,0025,0043,1.7647E-01,1.5810E-03,5.0163E-01  
-358,0025,0054,1.7647E-01,1.5810E-03,6.8780E-02  
-359,0025,0064,1.7647E-01,1.5810E-03,1.8250E-02  
-360,0043,0054,1.7647E-01,6.9838E-03,2.4620E-02  
-361,0054,0064,1.7647E-01,1.4827E-02,1.5880E-02  
-362,0064,0074,1.7647E-01,1.4827E-02,1.6030E-02  
-363,0074,0086,1.7647E-01,5.9323E-03,2.7450E-02  
-364,0086,0100,1.7647E-01,6.8405E-03,7.2530E-02  
-365,0089,0100,1.7647E-01,7.8540E-05,3.4583E-01  
-366,0089,0109,1.7647E-01,7.8540E-05,3.3180E-01  
-367,0089,0117,1.7647E-01,7.8540E-05,3.5640E-02  
-368,0089,0116,1.7647E-01,7.8540E-05,1.1606E-01  
-369,0089,0115,1.7647E-01,7.8540E-05,8.6900E-02  
-370,0089,0114,1.7647E-01,7.8540E-05,5.1920E-02  
-371,0089,0113,1.7647E-01,7.8540E-05,3.1850E-02

-372,0090,0100,1.7647E-01,6.2832E-04,3.5624E-01  
-373,0090,0109,1.7647E-01,6.2832E-04,3.2624E-01  
-374,0090,0117,1.7647E-01,6.2832E-04,3.5560E-02  
-375,0090,0116,1.7647E-01,6.2832E-04,1.1510E-01  
-376,0090,0115,1.7647E-01,6.2832E-04,8.5360E-02  
-377,0090,0114,1.7647E-01,6.2832E-04,5.0610E-02  
-378,0090,0113,1.7647E-01,6.2832E-04,3.0890E-02  
-379,0091,0100,1.7647E-01,1.2566E-03,3.8497E-01  
-380,0091,0109,1.7647E-01,1.2566E-03,3.1014E-01  
-381,0091,0117,1.7647E-01,1.2566E-03,3.5280E-02  
-382,0091,0116,1.7647E-01,1.2566E-03,1.1240E-01  
-383,0091,0115,1.7647E-01,1.2566E-03,8.1340E-02  
-384,0091,0114,1.7647E-01,1.2566E-03,4.7320E-02  
-385,0091,0113,1.7647E-01,1.2566E-03,2.8550E-02  
-386,0092,0100,1.7647E-01,2.4544E-03,4.4490E-01  
-387,0092,0109,1.7647E-01,2.4544E-03,2.7379E-01  
-388,0092,0117,1.7647E-01,2.4544E-03,3.4480E-02  
-389,0092,0116,1.7647E-01,2.4544E-03,1.0666E-01  
-390,0092,0115,1.7647E-01,2.4544E-03,7.3900E-02  
-391,0092,0114,1.7647E-01,2.4544E-03,4.1650E-02  
-392,0092,0113,1.7647E-01,2.4544E-03,2.4620E-02  
-393,0093,0100,1.7647E-01,4.6078E-03,5.6253E-01  
-394,0093,0109,1.7647E-01,4.6078E-03,1.9631E-01  
-395,0093,0117,1.7647E-01,4.6078E-03,3.2270E-02  
-396,0093,0116,1.7647E-01,4.6078E-03,9.5060E-02  
-397,0093,0115,1.7647E-01,4.6078E-03,6.1570E-02  
-398,0093,0114,1.7647E-01,4.6078E-03,3.3160E-02  
-399,0093,0113,1.7647E-01,4.6078E-03,1.9100E-02  
-400,0100,0109,1.7647E-01,1.4804E-02,1.9056E-01  
-401,0100,0117,1.7647E-01,1.4755E-02,1.4840E-02  
-402,0100,0116,1.7647E-01,5.3721E-04,5.7330E-02  
-403,0100,0115,1.7647E-01,2.8740E-03,4.5610E-02  
-404,0100,0114,1.7647E-01,1.5217E-02,2.6450E-02  
-405,0100,0113,1.7647E-01,1.5217E-02,1.5680E-02  
-406,0109,0117,1.7647E-01,1.4755E-02,6.9410E-02  
-407,0109,0116,1.7647E-01,1.4755E-02,1.5831E-01  
-408,0109,0115,1.7647E-01,1.4755E-02,7.3760E-02  
-409,0109,0114,1.7647E-01,1.4755E-02,3.2650E-02  
-410,0109,0113,1.7647E-01,1.4755E-02,1.6930E-02  
-411,0112,0118,1.7647E-01,7.8540E-05,1.8050E-02  
-412,0112,0126,1.7647E-01,7.8540E-05,2.2210E-02  
-413,0112,0132,1.7647E-01,7.8540E-05,6.9300E-03  
-414,0112,0131,1.7647E-01,7.8540E-05,4.0830E-02  
-415,0112,0130,1.7647E-01,7.8540E-05,9.2010E-02  
-416,0112,0129,1.7647E-01,7.8540E-05,2.0665E-01  
-417,0112,0128,1.7647E-01,7.8540E-05,4.7301E-01  
-418,0112,0127,1.7647E-01,7.8540E-05,1.4031E-01  
-419,0113,0118,1.7647E-01,6.2832E-04,1.9420E-02  
-420,0113,0126,1.7647E-01,6.2832E-04,2.3670E-02  
-421,0113,0132,1.7647E-01,6.2832E-04,7.9600E-03  
-422,0113,0131,1.7647E-01,6.2832E-04,5.0320E-02  
-423,0113,0130,1.7647E-01,6.2832E-04,1.3181E-01  
-424,0113,0129,1.7647E-01,6.2832E-04,3.1154E-01  
-425,0113,0128,1.7647E-01,6.2832E-04,3.9613E-01  
-426,0113,0127,1.7647E-01,6.2832E-04,5.9150E-02  
-427,0114,0118,1.7647E-01,1.2566E-03,2.3910E-02  
-428,0114,0126,1.7647E-01,1.2566E-03,2.8250E-02  
-429,0114,0132,1.7647E-01,1.2566E-03,1.1650E-02

-430,0114,0131,1.7647E-01,1.2566E-03,8.9090E-02  
 -431,0114,0130,1.7647E-01,1.2566E-03,2.9233E-01  
 -432,0114,0129,1.7647E-01,1.2566E-03,3.8614E-01  
 -433,0114,0128,1.7647E-01,1.2566E-03,1.5572E-01  
 -434,0114,0127,1.7647E-01,1.2566E-03,1.2910E-02  
 -435,0115,0118,1.7647E-01,2.4544E-03,3.9180E-02  
 -436,0115,0126,1.7647E-01,2.4544E-03,3.9320E-02  
 -437,0115,0132,1.7647E-01,2.4544E-03,2.6240E-02  
 -438,0115,0131,1.7647E-01,2.4544E-03,2.6346E-01  
 -439,0115,0130,1.7647E-01,2.4544E-03,4.4540E-01  
 -440,0115,0129,1.7647E-01,2.4544E-03,1.4971E-01  
 -441,0115,0128,1.7647E-01,2.4544E-03,3.6690E-02  
 -442,0116,0118,1.7647E-01,4.2082E-03,1.4882E-01  
 -443,0116,0126,1.7647E-01,4.2082E-03,5.5580E-02  
 -444,0116,0132,1.7647E-01,4.2082E-03,1.1159E-01  
 -445,0116,0131,1.7647E-01,4.2082E-03,4.9531E-01  
 -446,0116,0130,1.7647E-01,4.2082E-03,1.5378E-01  
 -447,0116,0129,1.7647E-01,4.2082E-03,3.4920E-02  
 -448,0117,0118,1.7647E-01,1.0508E-03,4.3510E-01  
 -449,0117,0126,1.7647E-01,1.0508E-03,1.0350E-02  
 -450,0117,0132,1.7647E-01,1.0508E-03,1.7494E-01  
 -451,0117,0131,1.7647E-01,1.0508E-03,3.2188E-01  
 -452,0117,0130,1.7647E-01,1.0508E-03,4.4180E-02  
 -453,0117,0129,1.7647E-01,1.0508E-03,1.3550E-02  
 -454,0118,0126,1.7647E-01,1.4954E-03,2.0720E-02  
 -455,0118,0132,1.7647E-01,2.6154E-03,4.8040E-02  
 -456,0118,0131,1.7647E-01,2.6154E-03,2.1840E-01  
 -457,0118,0130,1.7647E-01,2.6154E-03,5.4060E-02  
 -458,0118,0129,1.7647E-01,2.6154E-03,1.8370E-02  
 -459,0118,0128,1.7647E-01,2.6154E-03,8.4400E-03  
 -460,0118,0126,1.7647E-01,1.0744E-03,3.1006E-01  
 -461,0118,0132,1.7647E-01,1.0744E-03,5.8899E-01  
 -462,0118,0131,1.7647E-01,1.0744E-03,1.0095E-01  
 -463,0126,0132,1.7647E-01,1.4954E-03,3.7720E-01  
 -464,0126,0131,1.7647E-01,1.4954E-03,8.5330E-02  
 -465,0126,0130,1.7647E-01,1.4954E-03,2.1880E-02

COMM

COMM Contact resistances between bottom of container and drum bottom

COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0466,0001,0143,1.8928E+03,7.8540E-05,1.0000E+00  
 0467,0002,0143,1.8928E+03,6.2832E-04,1.0000E+00  
 0468,0003,0143,1.8928E+03,1.2566E-03,1.0000E+00  
 0469,0004,0143,1.8928E+03,2.4544E-03,1.0000E+00  
 0470,0005,0143,1.8928E+03,4.2082E-03,1.0000E+00  
 0471,0006,0143,1.8928E+03,3.6458E-03,1.0000E+00

COMM

COMM Radial convection paths between container side and drum gas

COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0472,0012,0163,3.5800E+00,3.5343E-03,1.0000E+00  
 0473,0046,0163,3.5800E+00,8.2467E-03,1.0000E+00  
 0474,0056,0163,3.5800E+00,1.6258E-02,1.0000E+00  
 0475,0066,0163,3.5800E+00,1.6258E-02,1.0000E+00  
 0476,0076,0163,3.5800E+00,6.5047E-03,1.0000E+00  
 0477,0088,0164,3.5800E+00,7.5006E-03,1.0000E+00  
 0478,0102,0164,3.5800E+00,1.6233E-02,1.0000E+00  
 0479,0111,0164,3.5800E+00,1.6179E-02,1.0000E+00

0480,0126,0164,3.5800E+00,5.1051E-03,1.0000E+00  
 0481,0132,0164,3.5800E+00,3.9270E-03,1.0000E+00  
 COMM  
 COMM Axial convection paths between container top and drum gas  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0482,0132,0166,3.7000E+00,3.6458E-03,1.0000E+00  
 0483,0131,0166,3.7000E+00,4.2082E-03,1.0000E+00  
 0484,0130,0166,3.7000E+00,2.4544E-03,1.0000E+00  
 0485,0129,0166,3.7000E+00,1.2566E-03,1.0000E+00  
 0486,0128,0166,3.7000E+00,6.2832E-04,1.0000E+00  
 0487,0127,0166,3.7000E+00,7.8540E-05,1.0000E+00  
 COMM  
 COMM Radial convection paths between drum inner gas and inside of cylinder  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0488,0163,0148,1.6500E+00,7.1614E-02,1.0000E+00  
 0489,0164,0149,1.6500E+00,6.8997E-02,1.0000E+00  
 0490,0165,0150,1.6500E+00,7.8215E-02,1.0000E+00  
 COMM  
 COMM Radial convection paths between outside of cylinder and drum outer gas  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0491,0148,0167,1.6500E+00,7.2260E-02,1.0000E+00  
 0492,0149,0168,1.6500E+00,6.9619E-02,1.0000E+00  
 0493,0150,0169,1.6500E+00,7.8920E-02,1.0000E+00  
 COMM  
 COMM Radial convection paths between drum outer gas and inside of drum side  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0494,0171,0157,1.6500E+00,2.3055E-02,1.0000E+00  
 0495,0167,0159,1.6500E+00,1.4452E-01,1.0000E+00  
 0496,0168,0160,1.6500E+00,1.3924E-01,1.0000E+00  
 0497,0169,0161,1.6500E+00,1.5784E-01,1.0000E+00  
 COMM  
 COMM Axial convection paths between drum gas and drum top and bottom  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0498,0170,0143,9.6000E-01,1.2272E-02,1.0000E+00  
 0499,0170,0144,9.6000E-01,1.2557E-02,1.0000E+00  
 0500,0171,0146,9.6000E-01,7.4486E-02,1.0000E+00  
 0501,0144,0163,1.9000E+00,1.2115E-02,1.0000E+00  
 0502,0146,0167,1.9000E+00,7.4486E-02,1.0000E+00  
 0503,0166,0152,1.9000E+00,1.2272E-02,1.0000E+00  
 0504,0165,0152,1.9000E+00,1.2115E-02,1.0000E+00  
 0505,0169,0154,1.9000E+00,7.4486E-02,1.0000E+00  
 COMM  
 COMM Radial conduction paths between gas nodes  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0506,0170,0171,1.2905E-01,1.1528E-02,7.1540E-02  
 0507,0166,0165,1.2905E-01,5.5483E-02,3.4199E-02  
 COMM  
 COMM Axial conduction paths between gas nodes  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0508,0163,0164,1.2905E-01,1.2115E-02,1.2700E-01  
 0509,0164,0165,1.2905E-01,1.2115E-02,1.3296E-01

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0510,0167,0168,1.2905E-01,7.4486E-02,1.2700E-01
0511,0168,0169,1.2905E-01,7.4486E-02,1.3296E-01
COMM
COMM Radial conduction paths between metal nodes
COMM C#, N1, N2, K or H , AREA , DR or 1
COMM (m^2) , (m or -)
0512,0143,0144,5.1510E+01,6.2341E-04,3.4573E-02
0513,0144,0145,5.1510E+01,8.8674E-04,1.2958E-02
0514,0145,0146,5.1510E+01,8.8674E-04,4.0729E-02
0515,0146,0158,5.1510E+01,1.7735E-03,4.2577E-02
0516,0152,0153,5.1510E+01,8.8674E-04,3.0810E-02
0517,0153,0154,5.1510E+01,8.8674E-04,4.0729E-02
0518,0154,0155,5.1510E+01,1.7735E-03,4.1783E-02
COMM
COMM Axial conduction paths between metal nodes
COMM C#, N1, N2, K or H , AREA , DX or 1
COMM (m^2) , (m or -)
0519,0147,0148,5.1510E+01,4.4139E-04,6.4682E-02
0520,0148,0149,5.1510E+01,4.4139E-04,1.2700E-01
0521,0149,0150,5.1510E+01,4.4139E-04,1.3296E-01
0522,0150,0151,5.1510E+01,4.4139E-04,7.0644E-02
0523,0156,0157,5.1510E+01,1.7814E-03,1.0716E-02
0524,0157,0158,5.1510E+01,1.7814E-03,1.0716E-02
0525,0158,0159,5.1510E+01,1.7814E-03,6.5079E-02
0526,0159,0160,5.1510E+01,1.7814E-03,1.2740E-01
0527,0160,0161,5.1510E+01,1.7814E-03,1.3376E-01
0528,0161,0162,5.1510E+01,1.7814E-03,7.1438E-02
COMM
COMM Contact resistances within the drum
COMM C#, N1, N2, K or H , AREA , DX or 1
COMM (m^2) , (m or -)
0529,0145,0147,1.8928E+03,4.4139E-04,1.0000E+00
0530,0151,0153,1.8928E+03,4.4139E-04,1.0000E+00
0531,0155,0162,1.8928E+03,9.0653E-03,1.0000E+00
COMM
COMM Radiation paths inside the drum
COMM C#, N1, N2, Emissivity, AREA , VIEW FACT
COMM (m^2) , ( - )
-532,0127,0150,1.7647E-01,7.8540E-05,7.2022E-01
-533,0127,0152,2.1951E-01,7.8540E-05,2.7978E-01
-534,0128,0150,1.7647E-01,6.2832E-04,7.2185E-01
-535,0128,0152,2.1951E-01,6.2832E-04,2.7815E-01
-536,0129,0150,1.7647E-01,1.2566E-03,7.2615E-01
-537,0129,0152,2.1951E-01,1.2566E-03,2.7385E-01
-538,0130,0150,1.7647E-01,2.4544E-03,7.3443E-01
-539,0130,0152,2.1951E-01,2.4544E-03,2.6557E-01
-540,0131,0150,1.7647E-01,4.2082E-03,7.4868E-01
-541,0131,0152,2.1951E-01,4.2082E-03,2.5132E-01
-542,0132,0150,1.7647E-01,3.6458E-03,7.6456E-01
-543,0132,0152,2.1951E-01,3.6458E-03,2.3544E-01
-544,0132,0149,1.7647E-01,3.9270E-03,6.0270E-01
-545,0132,0150,1.7647E-01,3.9270E-03,3.9730E-01
-546,0126,0149,1.7647E-01,5.1051E-03,7.8793E-01
-547,0126,0150,1.7647E-01,5.1051E-03,2.1207E-01
-548,0111,0148,1.7647E-01,1.6179E-02,1.1980E-02
-549,0111,0149,1.7647E-01,1.6179E-02,9.3038E-01
-550,0111,0150,1.7647E-01,1.6179E-02,5.7640E-02
-551,0102,0148,1.7647E-01,1.6233E-02,7.0510E-02

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-552,0102,0149,1.7647E-01,1.6233E-02,9.1893E-01  
 -553,0102,0150,1.7647E-01,1.6233E-02,1.0560E-02  
 -554,0088,0148,1.7647E-01,7.5006E-03,3.2001E-01  
 -555,0088,0149,1.7647E-01,7.5006E-03,6.7999E-01  
 -556,0076,0148,1.7647E-01,6.5047E-03,6.6038E-01  
 -557,0076,0149,1.7647E-01,6.5047E-03,3.3962E-01  
 -558,0066,0148,1.7647E-01,1.6258E-02,9.1928E-01  
 -559,0066,0149,1.7647E-01,1.6258E-02,8.0720E-02  
 -560,0056,0144,2.1951E-01,1.6258E-02,4.0660E-02  
 -561,0056,0148,1.7647E-01,1.6258E-02,9.4633E-01  
 -562,0056,0149,1.7647E-01,1.6258E-02,1.3010E-02  
 -563,0046,0144,2.1951E-01,8.2467E-03,1.8504E-01  
 -564,0046,0148,1.7647E-01,8.2467E-03,8.1496E-01  
 -565,0012,0144,2.1951E-01,3.5343E-03,4.0747E-01  
 -566,0012,0148,1.7647E-01,3.5343E-03,5.9253E-01  
 -567,0144,0148,2.1951E-01,1.2115E-02,6.2374E-01  
 -568,0144,0149,2.1951E-01,1.2115E-02,3.9230E-02  
 -569,0144,0150,2.1951E-01,1.2115E-02,1.0350E-02  
 -570,0144,0152,2.9032E-01,1.2115E-02,9.6900E-03  
 -571,0148,0149,1.7647E-01,7.1614E-02,4.5730E-02  
 -572,0148,0150,1.7647E-01,7.1614E-02,5.0300E-03  
 -573,0149,0150,1.7647E-01,6.8997E-02,7.8020E-02  
 -574,0149,0152,2.1951E-01,6.8997E-02,3.1620E-02  
 -575,0150,0152,2.1951E-01,7.8215E-02,2.4018E-01  
 -576,0150,0159,2.1951E-01,7.8920E-02,2.6220E-02  
 -577,0150,0160,2.1951E-01,7.8920E-02,1.6935E-01  
 -578,0150,0161,2.1951E-01,7.8920E-02,6.0874E-01  
 -579,0150,0154,2.1951E-01,7.8920E-02,1.9569E-01  
 -580,0149,0146,2.1951E-01,6.9619E-02,2.6500E-02  
 -581,0149,0159,2.1951E-01,6.9619E-02,1.8813E-01  
 -582,0149,0160,2.1951E-01,6.9619E-02,5.7073E-01  
 -583,0149,0161,2.1951E-01,6.9619E-02,1.9202E-01  
 -584,0149,0154,2.1951E-01,6.9619E-02,2.2620E-02  
 -585,0148,0146,2.1951E-01,7.2260E-02,2.0901E-01  
 -586,0148,0159,2.1951E-01,7.2260E-02,5.8209E-01  
 -587,0148,0160,2.1951E-01,7.2260E-02,1.8123E-01  
 -588,0148,0161,2.1951E-01,7.2260E-02,2.7660E-02  
 -589,0146,0159,2.9032E-01,7.4486E-02,5.0949E-01  
 -590,0146,0160,2.9032E-01,7.4486E-02,1.3507E-01  
 -591,0146,0161,2.9032E-01,7.4486E-02,5.6610E-02  
 -592,0146,0154,2.9032E-01,7.4486E-02,6.4700E-02  
 -593,0159,0160,2.9032E-01,1.4452E-01,9.7380E-02  
 -594,0159,0161,2.9032E-01,1.4452E-01,3.7450E-02  
 -595,0159,0154,2.9032E-01,1.4452E-01,2.5540E-02  
 -596,0160,0161,2.9032E-01,1.3924E-01,1.0611E-01  
 -597,0160,0154,2.9032E-01,1.3924E-01,6.5460E-02  
 -598,0161,0154,2.9032E-01,1.5784E-01,2.5046E-01  
 -599,0143,0157,7.8571E-01,1.2272E-02,1.5100E-02  
 -600,0144,0157,7.8571E-01,1.2557E-02,1.9870E-02  
 -601,0146,0157,7.8571E-01,7.4486E-02,1.3980E-01

COMM

COMM Convection and Radiation Conductors to boundary temperature nodes  
COMM

-602,0143,0172,5.8016E-01,1.2272E-02,9.8490E-01  
 -603,0144,0172,5.8016E-01,1.2557E-02,9.8013E-01  
 -604,0146,0172,5.8016E-01,7.4486E-02,8.6020E-01  
 -605,0157,0172,5.8016E-01,2.3055E-02,4.7182E-01  
 0606,0170,0172,1.2905E-01,2.4829E-02,2.2225E-02

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0607,0171,0172,1.2905E-01,7.4486E-02,2.2225E-02
0608,0156,0172,9.6000E-01,1.7814E-03,1.0000E+00
0609,0157,0173,1.6500E+00,2.4156E-02,1.0000E+00
0610,0159,0173,1.6500E+00,1.4670E-01,1.0000E+00
0611,0160,0173,1.6500E+00,1.4048E-01,1.0000E+00
0612,0161,0173,1.6500E+00,1.6104E-01,1.0000E+00
0613,0154,0173,1.9000E+00,7.6267E-02,1.0000E+00
0614,0152,0173,1.9000E+00,2.4829E-02,1.0000E+00
-615,0156,0172,5.8016E-01,1.7814E-03,1.0000E+00
-616,0157,0173,5.8016E-01,2.4156E-02,1.0000E+00
-617,0159,0173,5.8016E-01,1.4670E-01,1.0000E+00
-618,0160,0173,5.8016E-01,1.4048E-01,1.0000E+00
-619,0161,0173,5.8016E-01,1.6104E-01,1.0000E+00
-620,0154,0173,5.8016E-01,7.6267E-02,1.0000E+00
-621,0152,0173,5.8016E-01,2.4829E-02,1.0000E+00

ENDD
CNTL DATA
  TSTP=0.0
  BETA,0.5,
  DCONV,0.000001,
  NLOP,0,
  TEND,0.0,
  IPRT,0,
  ISTA,0,
  RLAX,1.0,
  IPRO,2,
ENDD
VAB1 DATA
  COMMON/HCOND/HKODX(33)
  DIMENSION DXH(33)
  DIMENSION AH(33),DLH(33),ICH(33),ISH(33),IGH(33),IDH(33)
  DIMENSION AA(41),DLA(41),ICA(41),ISA(41),IGA(41),IDA(41)
  DIMENSION IP(27),N1(27),N2(27),AP(27),DX(27)

C
C      DXH IS THE CONDUCTION HEAT-TRANSFER DISTANCE
C      BETWEEN SURFACE AND HELIUM NODES
  DATA DXH/  8.5680E-03, 7.9963E-03,3*1.2915E-02,
  1      5*9.2500E-03,6*2.0668E-02,6*2.0600E-02,
  2      4*6.0688E-03, 6.2610E-03,4*6.9424E-03,
  3      2*2.2973E-03/

C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
  DATA AH/2.4544E-03,3.2289E-03,7.8540E-05,6.2832E-04,
  1      1.2566E-03,7.8540E-05,6.2832E-04,1.2566E-03,
  2      2.4544E-03,4.2082E-03,7.8540E-05,6.2832E-04,
  3      1.2566E-03,2.4544E-03,4.2082E-03,3.9961E-04,
  4      7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
  5      4.2082E-03,1.5810E-03,2.6917E-03,6.5031E-03,
  6      6.5031E-03,2.6019E-03,5.0293E-03,1.3422E-02,
  7      1.3422E-02,5.3703E-03,5.2198E-03,1.4804E-02,
  8      1.4755E-02/

C
C      DLH IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
  DATA DLH/2*2.6600E-02,3*5.0000E-02,5*1.0320E-01,
  1      6*1.0720E-01,6*1.1400E-01,4*1.1283E-01,
  2      5*1.3500E-01,2*8.2536E-02/

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C
C      ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C          DATA ICH/035,036,078,079,080,089,090,091,092,093,095,
1          096,097,098,099,100,114,115,116,117,118,119,
2          174,176,178,180,203,204,205,206,207,223,224/
C
C      ISH IS THE SURFACE NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C          DATA ISH/034,035,142,141,140,089,090,091,092,093,089,
1          090,091,092,093,084,112,113,114,115,116,117,
2          136,137,138,139,041,052,062,072,082,100,109/
C
C      IGH IS THE HELIUM (GAS) NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C          DATA IGH/039,040,077,078,079,077,078,079,080,081,094,
1          095,096,097,098,099,103,104,105,106,107,108,
2          039,050,060,070,040,051,061,071,081,099,108/
C
C      IDH DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C          -1 = HORIZONTAL BOTTOM SURFACE
C          0 = VERTICAL SURFACE
C          1 = HORIZONTAL TOP SURFACE
C          DATA IDH/5*1,5*-1,6*1,6*-1,11*0/
C
C      AA IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C          VECTION HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C          DATA AA/3.5343E-03,8.2467E-03,1.6258E-02,1.6258E-02,
1          6.5047E-03,7.5006E-03,1.6233E-02,1.6179E-02,
2          5.1051E-03,3.9270E-03,3.6458E-03,4.2082E-03,
3          2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
4          7.1614E-02,6.8997E-02,7.8215E-02,7.2260E-02,
5          6.9619E-02,7.8920E-02,2.3055E-02,1.4452E-01,
6          1.3924E-01,1.5784E-01,1.2272E-02,1.2557E-02,
7          7.4486E-02,1.2115E-02,7.4486E-02,1.2272E-02,
8          1.2115E-02,7.4486E-02,1.7814E-03,2.4156E-02,
9          1.4670E-01,1.4048E-01,1.6104E-01,7.6267E-02,
A          2.4829E-02/
C
C      DLA IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR CON-
C          VECTION HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C          DATA DLA/10*2.5400E-01,6*1.2500E-01,6*3.9529E-01,
1          2.0637E-02,3*3.9529E-01,3*3.5560E-01,
2          2.5606E-02,8.8900E-02,2*1.7621E-01,
3          8.8900E-02,1.5875E-03,4*4.1910E-01,
4          2*3.5877E-01/
C
C      ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C          DATA ICA/472,473,474,475,476,477,478,479,480,481,
1          482,483,484,485,486,487,488,489,490,491,
2          492,493,494,495,496,497,498,499,500,501,
3          502,503,504,505,608,609,610,611,612,613,
4          614/
C
C      ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES

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DATA ISA/012,046,056,066,076,088,102,111,126,132,
1      132,131,130,129,128,127,148,149,150,148,
2      149,150,157,159,160,161,143,144,146,144,
3      146,152,152,154,156,157,159,160,161,154,
4      152/
C
C      IGA IS THE HELIUM (GAS) NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA IGA/5*163,5*164,6*166,163,164,165,167,168,
1      169,171,167,168,169,2*170,171,163,167,
2      166,165,169,172,6*173/
C
C      IDA DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C          -1 = HORIZONTAL BOTTOM SURFACE
C          0 = VERTICAL SURFACE
C          1 = HORIZONTAL TOP SURFACE
DATA IDA/10*0,6*1,10*0,3*-1,2*1,4*-1,4*0,2*1/
C
C      IP IS THE HEAT-TRANSFER PATH NUMBER FOR CONDUCTION
C          HEAT TRANSFER BETWEEN PU-METAL NODES
DATA IP/ 32, 33, 34, 45, 46, 47, 55, 56, 57,
1      65, 66, 67, 75, 76, 77,143,144,145,
2      146,158,159,160,161,173,175,177,179/
C
C      N1 IS THE FIRST PU-METAL NODE NUMBER
DATA N1/133,134,135, 36, 37, 38, 47, 48, 49,
1      57, 58, 59, 67, 68, 69, 36, 47, 57,
2      67, 37, 48, 58, 68, 38, 49, 59, 69/
C
C      N2 IS THE SECOND PU-METAL NODE NUMBER
DATA N2/ 36, 37, 38, 47, 48, 49, 57, 58, 59,
1      67, 68, 69,142,141,140, 37, 48, 58,
2      68, 38, 49, 59, 69,136,137,138,139/
C
C      AP IS THE CONDUCTION HEAT-TRANSFER AREA
C          BETWEEN PU-METAL VOLUME AND SURFACE NODES
DATA AP/7.8540E-05,6.2832E-04,1.2566E-03,
1      7.8540E-05,6.2832E-04,1.2566E-03,
2      7.8540E-05,6.2832E-04,1.2566E-03,
3      7.8540E-05,6.2832E-04,1.2566E-03,
4      7.8540E-05,6.2832E-04,1.2566E-03,
5      5.3834E-04,2*1.3006E-03,5.2037E-04,
6      1.6150E-03,2*3.9019E-03,1.5611E-03,
7      2.6917E-03,2*6.5031E-03,2.6019E-03/
C
C      DX IS CONDUCTION HEAT-TRANSFER DISTANCE
C          BETWEEN PU-METAL NODES
DATA DX/3*8.5680E-03,3*2.9268E-02,3*4.1400E-02,
1      3*2.8982E-02,3*4.6169E-03,4*5.7565E-03,
2      4*9.1783E-03,4*4.8208E-03/
C
C      HELIUM THERMAL CONDUCTIVITY = HTK0*(0.5*(TL+TR)+HTK1)**HTK2
C      HELIUM SPECIFIC HEAT = HSH0
C      HELIUM VISCOSITY = HVI0+AHVII1*(TL+TR)+AQVI2*(TL+TR)**2
C      HELIUM DENSITY = HDNO/(HDN1+273.16)
C
DATA HTK0/3.3366E-03/,HTK1/2.7316E+02/,HTK2/6.6800E-01/

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DATA HVI0/6.8531E-02/,HHVI1/7.85947E-05/,HQVI2/-1.38105E-08/
DATA HDN0/4.8792E+01/,HDN1/2.7316E+02/,HSH0/1.4539E+00/
C
C   AIR THERMAL CONDUCTIVITY = ATK0+AHTK1*( TL+TR )+AQTK2*( TL+TR )**2
C   AIR SPECIFIC HEAT = ASH0+AHSH1*( TL+TR )+AQSH2*( TL+TR )**2
C   AIR VISCOSITY = AVI0+AHVI1*( TL+TR )+AQVI2*( TL+TR )**2
C   AIR DENSITY = ADN0/(ADN1+T) WHERE T,TL,&TR ARE TEMPERATURES
C
C
DATA ATK0/2.3991E-02/,AHTK1/3.30685E-05/,AQTK2/-3.49125E-09/
DATA ASH0/2.7625E-01/,AHSH1/2.72465E-05/,AQSH2/-1.36857E-09/
DATA AVI0/6.1474E-02/,AHVI1/1.06686E-04/,AQVI2/-7.3260E-08/
DATA ADN0/3.5308E+02/,ADN1/2.7316E+02/
C
C   EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C   A HORIZONTAL OR VERTICAL SURFACE TO A HELIUM VOLUME
C
DO 100 I=1,33
TA=T(ISSH(I))+T(IGH(I))
TK=HTK0*(HTK1+0.5*TA)**HTK2
SH=HSH0
VI=HVI0+TA*(HHVI1+TA*HQVI2)
DG=HDN0/(HDN1+0.5*TA)
DT=DMAX1(0.1,DABS(T(ISSH(I))-T(IGH(I))))
D3=DLH(I)*DLH(I)*DLH(I)
GR=D3*1.27094E+08*DG*DG*DT/((HDN1+T(IGH(I)))*VI*VI)
PR=SH*VI/TK
GRPR=GR*PR
IF (IDH(I).NE.0) THEN
C
C   HORIZONTAL SURFACE TO HELIUM NUSSELT NUMBER
C
IF (((IDH(I).EQ.-1).AND.(T(IGH(I)).GE.T(ISSH(I))))OR.
1    ((IDH(I).EQ. 1).AND.(T(IGH(I)).LE.T(ISSH(I))))) THEN
C
C   HOTTER SURFACE FACING UPWARD OR
C   COLDER SURFACE FACING DOWNWARD
C
IF (GRPR.LT.1.0844E+07) THEN
  F=DMIN1(5.0,0.43429*DLOG(GRPR))
  CNU=((F-2.0)*0.54*(GRPR**0.25)
1      +(5.0-F)*0.96*(GRPR**0.20))*0.33333
ELSE
  CNU=0.14*(GRPR**0.33333)
ENDIF
ELSE
C
C   COLDER SURFACE FACING UPWARD OR
C   HOTTER SURFACE FACING DOWNWARD
C
  F=DMIN1(5.5,0.43429*DLOG(GRPR))
  CNU=((F-2.5)*0.27*(GRPR**0.25)
1      +(5.5-F)*0.48*(GRPR**0.20))*0.33333
ENDIF
ELSE
C
C   VERTICAL SURFACE TO HELIUM NUSSELT NUMBER
C
IF (GRPR.LT.7.6372E+07) THEN

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        F=DMIN1(5.0,0.43429*DLOG(GRPR))
        CNU=((F-2.0)*0.59*(GRPR**0.25)
1      +(5.0-F)*1.05*(GRPR**0.20))*0.33333
        ELSE
          CNU=0.13*(GRPR**0.33333)
        ENDIF
      ENDIF
      HKODX(I)=TK/DXH(I)
      G(ICH(I))=AH(I)*DMAX1(HKODX(I),CNU*TK/DLH(I))
100  CONTINUE
C
C      EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C      A HORIZONTAL OR VERTICAL SURFACE TO AN AIR VOLUME
C
      DO 110 I=1,41
      TA=T(ISA(I))+T(IGA(I))
      TK=ATK0+TA*(AHTK1+TA*AQTK2)
      SH=ASH0+TA*(AHSH1+TA*AQSH2)
      VI=AVI0+TA*(AHVI1+TA*AQVI2)
      DG=ADN0/(ADN1+0.5*TA)
      DT=DMAX1(0.1,DABS(T(ISA(I))-T(IGA(I))))
      D3=DLA(I)*DLA(I)*DLA(I)
      GR=D3*1.27094E+08*DG*DG*DT/((ADN1+T(IGA(I)))*VI*VI)
      PR=SH*VI/TK
      GRPR=GR*PR
      IF(IDA(I).NE.0) THEN
C
C          HORIZONTAL SURFACE TO AIR NUSSELT NUMBER
C
1      IF (((IDA(I).EQ.-1).AND.(T(IGA(I)).GE.T(ISA(I)))).OR.
1      ((IDA(I).EQ. 1).AND.(T(IGA(I)).LE.T(ISA(I))))) THEN
C
C          HOTTER SURFACE FACING UPWARD OR
C          COLDER SURFACE FACING DOWNWARD
C
1      IF (GRPR.LT.1.0844E+07) THEN
          F=DMIN1(5.0,0.43429*DLOG(GRPR))
          CNU=((F-2.0)*0.54*(GRPR**0.25)
1      +(5.0-F)*0.96*(GRPR**0.20))*0.33333
        ELSE
          CNU=0.14*(GRPR**0.33333)
        ENDIF
      ELSE
C
C          COLDER SURFACE FACING UPWARD OR
C          HOTTER SURFACE FACING DOWNWARD
C
1      F=DMIN1(5.5,0.43429*DLOG(GRPR))
      CNU=((F-2.5)*0.27*(GRPR**0.25)
1      +(5.5-F)*0.48*(GRPR**0.20))*0.33333
        ENDIF
      ELSE
C
C          VERTICAL SURFACE TO AIR NUSSELT NUMBER
C
1      IF (GRPR.LT.7.6372E+07) THEN
          F=DMIN1(5.0,0.43429*DLOG(GRPR))
          CNU=((F-2.0)*0.59*(GRPR**0.25)

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1           +(5.0-F)*1.05*(GRPR**0.20))*0.33333
      ELSE
        CNU=0.13*(GRPR**0.33333)
      ENDIF
    ENDIF
    G(ICA(I))=AA(I)*CNU*TK/DLA(I)
110 CONTINUE
C
C   EVALUATE THE TEMPERATURE-DEPENDENT THERMAL
C   CONDUCTIVITY OF THE PLUTONIUM-METAL INGOT
C
      DO 120 I=1,27
      TA=0.5*(T(N1(I))+T(N2(I)))
      TK=6.15856+TA*(2.11264E-02+TA*2.0E-05)
      G(IP(I))=AP(I)*TK/DX(I)
120 CONTINUE
ENDD
VAB2 DATA
ENDD
VAB3 DATA
      COMMON/HCOND/HKODX(33)
      DIMENSION AH(33),AA(41),H(41),ICH(33),ISH(33)
      DIMENSION ICA(41),ISA(41),IGA(41),IS1(46),IS2(46)
      DIMENSION ADM(10),IDM(10)
      DIMENSION IRT(6),IRS(9),APU(10),ACN(21),ICN(21)
C
C   IRT IS THE CONTAINER NODE NUMBER FOR RADIATION FROM THE
C   TOP OF THE PU-METAL INGOT TO THE VOLLRATH CONTAINER
      DATA IRT/82,93,92,91,90,89/
C
C   IRS IS THE CONTAINER NODE NUMBER FOR RADIATION FROM THE
C   SIDE OF THE PU-METAL INGOT TO THE VOLLRATH CONTAINER
      DATA IRS/34,35,41,52,62,72,82,93,92/
C
C   APU IS THE HEAT-TRANSFER AREA OF THE PU-METAL INGOT
C   SURFACE NODES
      DATA APU/7.8540E-05,6.2832E-04,1.2566E-03,2.6917E-03,
1          6.5031E-03,6.5031E-03,2.0262E-03,1.2566E-03,
2          6.2832E-04,7.8540E-05/
C
C   ACN IS THE HEAT-TRANSFER AREA OF THE BNFL CONTAINER
C   SURFACE NODES
      DATA ACN/7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
1          4.2082E-03,3.6458E-03,3.5343E-03,8.2467E-03,
2          1.6258E-02,1.6258E-02,6.5047E-03,7.5006E-03,
3          1.6233E-02,1.6179E-02,5.1051E-03,7.5728E-03,
4          4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
5          7.8540E-05/
C
C   ICN IS THE BNFL CONTAINER SURFACE NODE NUMBER
      DATA ICN/001,002,003,004,005,006,012,046,056,066,076,
1          088,102,111,126,132,131,130,129,128,127/
C
C   ADM IS THE HEAT-TRANSFER AREA OF THE DRUM OUTER-
C   SURFACE NODES
      DATA ADM/1.2272E-02,1.2557E-02,7.4486E-02,4.7211E-02,
1          1.7814E-03,1.4670E-01,1.4048E-01,1.6104E-01,
2          7.6267E-02,2.4829E-02/

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C
C      IDM IS THE DRUM OUTER-SURFACE NODE NUMBER
C      DATA IDM/143,144,146,157,156,159,160,161,154,152/
C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      DATA AH/2.4544E-03,3.2289E-03,7.8540E-05,6.2832E-04,
1          1.2566E-03,7.8540E-05,6.2832E-04,1.2566E-03,
2          2.4544E-03,4.2082E-03,7.8540E-05,6.2832E-04,
3          1.2566E-03,2.4544E-03,4.2082E-03,3.9961E-04,
4          7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
5          4.2082E-03,1.5810E-03,2.6917E-03,6.5031E-03,
6          6.5031E-03,2.6019E-03,5.0293E-03,1.3422E-02,
7          1.3422E-02,5.3703E-03,5.2198E-03,1.4804E-02,
8          1.4755E-02/
C
C      ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      DATA ICH/035,036,078,079,080,089,090,091,092,093,095,
1          096,097,098,099,100,114,115,116,117,118,119,
2          174,176,178,180,203,204,205,206,207,223,224/
C
C      ISH IS THE SURFACE NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      DATA ISH/034,035,142,141,140,089,090,091,092,093,089,
1          090,091,092,093,084,112,113,114,115,116,117,
2          136,137,138,139,041,052,062,072,082,100,109/
C
C      AA IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C      DATA AA/3.5343E-03,8.2467E-03,1.6258E-02,1.6258E-02,
1          6.5047E-03,7.5006E-03,1.6233E-02,1.6179E-02,
2          5.1051E-03,3.9270E-03,3.6458E-03,4.2082E-03,
3          2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
4          7.1614E-02,6.8997E-02,7.8215E-02,7.2260E-02,
5          6.9619E-02,7.8920E-02,2.3055E-02,1.4452E-01,
6          1.3924E-01,1.5784E-01,1.2272E-02,1.2557E-02,
7          7.4486E-02,1.2115E-02,7.4486E-02,1.2272E-02,
8          1.2115E-02,7.4486E-02,1.7814E-03,2.4156E-02,
9          1.4670E-01,1.4048E-01,1.6104E-01,7.6267E-02,
A          2.4829E-02/
C
C      ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C      DATA ICA/472,473,474,475,476,477,478,479,480,481,
1          482,483,484,485,486,487,488,489,490,491,
2          492,493,494,495,496,497,498,499,500,501,
3          502,503,504,505,608,609,610,611,612,613,
4          614/
C
C      ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C      DATA ISA/012,046,056,066,076,088,102,111,126,132,
1          132,131,130,129,128,127,148,149,150,148,
2          149,150,157,159,160,161,143,144,146,144,
3          146,152,152,154,156,157,159,160,161,154,
4          152/

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C      IGA IS THE AIR NODE NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C      DATA IGA/5*163,5*164,6*166,163,164,165,167,168,
1          169,171,167,168,169,2*170,171,163,167,
2          166,165,169,172,6*173/
C
C      IS1 IS THE CONTAINER SURFACE NODE NUMBER FOR RADIATION
C          HEAT TRANSFER BETWEEN CONTAINER OUTER- AND DRUM
C          INNER-SURFACE NODES
C      DATA IS1/2*127,2*128,2*129,2*130,2*131,4*132,2*126,
1          3*111,3*102,2*088,2*076,2*066,3*056,2*046,
2          2*012,143,144,146,157,156,157,159,160,
3          161,154,152/
C
C      IS2 IS THE DRUM SURFACE NODE NUMBER FOR RADIATION HEAT
C          TRANSFER BETWEEN CONTAINER OUTER- AND DRUM INNER-
C          SURFACE NODES
C      DATA IS2/150,152,150,152,150,152,150,152,150,152,
1          150,152,149,150,149,150,148,149,150,148,
2          149,150,148,149,148,149,148,149,144,148,
3          149,144,148,144,148,5*172,6*173/
C
C      DO 100 I=1,33
C          H(I)=G(ICH(I))/AH(I)
100 CONTINUE
      WRITE(6,110)
110 FORMAT('/[H.T.PATH] HEAT-TRANSFER COEFFICIENT (W/M**2/C)')
      I2=0
      DO 130 J=1,7
      I1=I2+1
      I2=MIN0(I2+5,33)
      WRITE(6,120) (ICH(I),H(I),I=I1,I2)
      WRITE(6,120) (ICH(I),HKODX(I),I=I1,I2)
120 FORMAT(' [',I3,']=',F8.5,' [',I3,']=',F8.5,' [',I3,']=',
      1      F8.5,' [',I3,']=',F8.5,' [',I3,']=',F8.5)
130 CONTINUE
C
C      PU-METAL INGOT OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
      QCDB=0.0
      QCDS=0.0
      QCDT=0.0
      DO 140 I=29,31
      QCDB=QCDB+G(I)*(T(I+104)-T(I+2))
140 CONTINUE
C
      QCVB=0.0
      QCVS=0.0
      QCVT=0.0
      DO 150 I=78,80
      QCVT=QCVT+G(I)*(T(220-I)-T(I-1))
150 CONTINUE
      DO 160 I=174,180,2
      J=I*5-830
      IF (I.EQ.174) J=39
      QCVS=QCVS+G(I)*(T(I/2+49)-T(J))
160 CONTINUE
C

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QRDB=0.0
QRDS=0.0
QRDT=0.0
DO 170 I=263,280
J=142-(I-263)/6
K=MOD(I-263,6)+1
QRDT=QRDT+G(I)*((T(J)+273.16)**4-(T(IRT(K))+273.16)**4)
170 CONTINUE
DO 180 I=281,304
IF (I.LT.287) THEN
  J=139
  K=I-277
ELSEIF (I.LT.293) THEN
  J=138
  K=I-284
ELSEIF (I.LT.300) THEN
  J=137
  K=I-292
ELSE
  J=136
  K=I-299
ENDIF
QRDS=QRDS+G(I)*((T(J)+273.16)**4-(T(IRS(K))+273.16)**4)
180 CONTINUE
C
QCD=QCDB+QCDS+QCDT
QCV=QCVB+QCVS+QCVT
QRD=QRDB+QRDS+QRDT
TOT=QCD+QCV+QRD
FCD=QCD/TOT
FCDB=QCDB/TOT
FCDS=QCDS/TOT
FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,190) QCD,QCDB,QCDS,QCDT,
1           QCV,QCVB,QCVS,QCVT,
2           QRD,QRDB,QRDS,QRDT,
3           TOT,
4           FCD,FCDB,FCDS,FCDT,
5           FCV,FCVB,FCVS,FCVT,
6           FRD,FRDB,FRDS,FRDT
190 FORMAT(/' HEAT TRANSFER FROM THE PU-METAL INGOT SURFACE'/
1           ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2           ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3           F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4           ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5           ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6           ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7           ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8           ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9           ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',

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A          F10.6)
C
TMX=0.0
TAV=0.0
ARW=0.0
DO 200 I=1,10
IF (TMX.LT.T(I+132)) THEN
IMX=I+132
TMX=T(IMX)
ENDIF
ARW=ARW+APU(I)
TAV=TAV+APU(I)*T(I+132)
200 CONTINUE
TAV=TAV/ARW
TAVF=TAV*1.8+32.0
TMXF=TMX*1.8+32.0
WRITE(6,210) TMX,TMXF,IMX,TAV,TAVF
210 FORMAT(/' TMX =',F9.4,' C =',F9.4,' F AT NODE ',I4/
1           ' TAV =',F9.4,' C =',F9.4,' F ')
C
C      CONTAINER OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
QCDB=0.0
QCDS=0.0
QCDT=0.0
DO 220 I=466,471
QCDB=QCDB+G(I)*(T(I-465)-T(143))
220 CONTINUE
QCD=QCDB
QCV=0.0
QCVB=0.0
J=163
DO 230 I=472,512
IF (I.LE.487) THEN
  IF (I.EQ.477) J=164
  IF (I.EQ.482) J=166
  QCV=QCV+G(I)*(T(ISA(I-471))-T(J))
  IF (I.EQ.481) QCVS=QCV
ENDIF
K=I
IF (I.GE.506) K=I+102
H(I-471)=G(K)/AA(I-471)
230 CONTINUE
QCVT=QCV-QCVS
WRITE(6,110)
WRITE(6,120) (I,H(I-471),I=472,505),(I,H(I-573),I=608,614)
QRD=0.0
QRDB=0.0
DO 240 I=532,566
QRD=QRD+G(I)*((T(IS1(I-531))+273.16)**4
1           -(T(IS2(I-531))+273.16)**4)
IF (I.EQ.543) QRDT=QRD
240 CONTINUE
QRDS=QRD-QRDT
TOT=QCD+QCV+QRD
FCD=QCD/TOT
FCDB=QCDB/TOT
FCDS=QCDS/TOT

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```

FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,250) QCD,QCDB,QCDS,QCDT,
1          QCV,QCVB,QCVS,QCVT,
2          QRD,QRDB,QRDS,QRDT,
3          TOT,
4          FCD,FCDB,FCDS,FCDT,
5          FCV,FCVB,FCVS,FCVT,
6          FRD,FRDB,FRDS,FRDT
250 FORMAT('' HEAT TRANSFER FROM THE BNFL CONTAINER SURFACE'/
1          ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2          ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3          F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4          ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5          ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6          ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7          ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8          ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9          ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A          F10.6)
C
TMX=0.0
TAV=0.0
ARW=0.0
DO 260 I=1,21
IF (TMX.LT.T(ICN(I))) THEN
  IMX=ICN(I)
  TMX=T(IMX)
ENDIF
ARW=ARW+ACN(I)
TAV=TAV+ACN(I)*T(ICN(I))
260 CONTINUE
TAV=TAV/ARW
TAVF=TAV*1.8+32.0
TMXF=TMX*1.8+32.0
WRITE(6,210) TMX,TMXF,IMX,TAV,TAVF
C
C      DRUM OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
QCDB=0.0
QCDS=0.0
QCDT=0.0
QCD=0.0
QCVB=G(498)*(T(143)-T(170))+G(499)*(T(144)-T(170))
1    +G(500)*(T(146)-T(171))+G(494)*(T(157)-T(171))
2    +G(608)*(T(156)-T(172))
QCVS=G(609)*(T(157)-T(173))+G(610)*(T(159)-T(173))
1    +G(611)*(T(160)-T(173))+G(612)*(T(161)-T(173))
QCVT=G(613)*(T(154)-T(173))+G(614)*(T(152)-T(173))
QCV=QCVB+QCVS+QCVT
X=(T(172)+273.16)**4

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Y=(T(173)+273.16)**4
QRDB=G(602)*((T(143)+273.16)**4-X)
1   +G(603)*((T(144)+273.16)**4-X)
2   +G(604)*((T(146)+273.16)**4-X)
3   +G(605)*((T(157)+273.16)**4-X)
4   +G(615)*((T(156)+273.16)**4-X)
QRDS=G(616)*((T(157)+273.16)**4-Y)
1   +G(617)*((T(159)+273.16)**4-Y)
2   +G(618)*((T(160)+273.16)**4-Y)
3   +G(619)*((T(161)+273.16)**4-Y)
QRDT=G(620)*((T(154)+273.16)**4-Y)
1   +G(621)*((T(152)+273.16)**4-Y)
QRD=QRDB+QRDS+QRDT
TOT=QCD+QCV+QRD
FCD=QCD/TOT
FCDB=QCDB/TOT
FCDS=QCDS/TOT
FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,270) QCD,QCDB,QCDS,QCDT,
1           QCV,QCVB,QCVS,QCVT,
2           QRD,QRDB,QRDS,QRDT,
3           TOT,
4           FCD,FCDB,FCDS,FCDT,
5           FCV,FCVB,FCVS,FCVT,
6           FRD,FRDB,FRDS,FRDT
270 FORMAT(/' HEAT TRANSFER FROM THE DRUM CONTAINER SURFACE'/
1       ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2       ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3       F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4       ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5       ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6       ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7       ' , FCDT =',F10.6/' FCV =',F10.6,' , FCVB =',F10.6,
8       ' , FCVS =',F10.6,' , FCVT =',F10.6/' FRD =',F10.6,
9       ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A     F10.6)
C
TMX=0.0
TAV=0.0
ARW=0.0
DO 280 I=1,10
IF (TMX.LT.T(IDM(I))) THEN
  IMX=IDM(I)
  TMX=T(IMX)
ENDIF
ARW=ARW+ADM(I)
TAV=TAV+ADM(I)*T(IDM(I))
280 CONTINUE
TAV=TAV/ARW
TAVF=TAV*1.8+32.0

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```
TMXF=TMX*1.8+32.0
WRITE(6,210) TMX,TMXF,IMX,TAV,TAVF
ENDD
USER DATA
ENDD
ENDD
```

## APPENDIX D

### TSAP INPUT DECK FOR PLUTONIUM-METAL BUTTONS—CABINET CASE

BNFL Container with Vollrath & Pu Buttons in a drum and in a cabinet  
NODE DMOD  
COMM  
COMM Initial Condition: T = 2.6667E+01 C  
COMM  
COMM Total Power = 15 W  
COMM Pu mass = 4.4 kg  
COMM Power den = 3.40909091 W/kg  
COMM  
COMM Material Properties  
COMM cp rho k emissivity  
COMM (W.h/kg.K) (kg/m^3) (W/m.K) (-)  
COMM Pu metal 3.9400E-02 1.9860E+04 6.5000E+00 5.0000E-01  
COMM Pu - He mix 3.5028E-01 1.5466E+04 5.0957E+00 3.8937E-01  
COMM SS 304 1.3442E-01 8.0243E+03 1.5130E+01 3.0000E-01  
COMM SS 316 1.3119E-01 7.9620E+03 1.3650E+01 3.0000E-01  
COMM He 1.4444E+00 1.2100E-01 1.5340E-01  
COMM Air 2.7972E-01 9.0880E-01 2.5810E-02  
COMM  
COMM k(Pu metal) = 6.15856 + 2.11264E-02\*TC + 2.0E-05\*TC\*\*2  
COMM = 6.5000E+00 W/m.K for TC = 15.92 C (60.66 F)  
COMM k(He gas) = 3.3366E-03\*(TC+273.16)\*\*0.668  
COMM = 1.5340E-01 W/m.K for TC = 35.02 C (95.04 F)  
COMM  
COMM Enhancement Factors - conduction represents convection  
COMM Enhancement Factor  
COMM Vollrath (general) 10  
COMM Vollrath narrow gaps, Ring 1-2 1  
COMM Ring 2-3 2  
COMM Ring 3-4 3  
COMM Ring 4-5 5  
COMM BNFL Inner (open regions only) 5  
COMM BNFL Outer (open regions only) 5  
COMM Drum 5  
COMM Cabinet Side 10  
COMM Cabinet Top 2  
COMM Bulk Air 1000  
COMM  
COMM Heat Transfer Coefficients (at 78.2 kPa)  
COMM htc (W/m^2.K)  
COMM Inside container conduction limited  
COMM Container, outside, vertical surface 2.20  
COMM Container, outside, top 2.47  
COMM Container, outside, bottom 1.47  
COMM Drum, vertical surfaces 1.65  
COMM Drum, inside, top surface 1.90  
COMM Drum, inside, bottom surface 0.96  
COMM Drum, outside, top surface 1.90  
COMM Drum, outside, bottom surface 0.96  
COMM Cabinet walls, vertical 1.41  
COMM Cabinet, inside top 1.84  
COMM Cabinet, inside bottom 0.62  
COMM

COMM Contact HTCs (W/m<sup>2</sup>.K) -- resistance = 1/HTC  
 COMM  
 COMM Vollrath side to lid (c84) 1892.8  
 COMM Ring 1 Ring 2 Ring 3 Ring 4 Ring 5 Ring 6  
 COMM Pu to Vollrath (c29-31) 1892.8 1892.8 1892.8  
 COMM BNFL in to out (c11-14) 1892.8 1892.8 1892.8 1892.8  
 COMM BNFL outb to ??? (n1-6) 1892.8 1892.8 1892.8 1892.8 1892.8 1892.8  
 COMM  
 COMM Radiation Heat Transfer  
 COMM Eff. Emissivity  
 COMM Pu & SS304 0.23077  
 COMM SS304 & SS304 0.17647  
 COMM SS304 & SS316 0.17647  
 COMM SS316 & SS316 0.17647  
 COMM Pu & Pu 0.33333  
 COMM  
 COMM N#, TEMP, SP.HEAT, DENSITY, VOLUME, POWER  
 COMM , (C), (W.h/kg.K), (kg/m<sup>3</sup>), (m<sup>3</sup>), (W)  
 0001,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0002,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0003,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0004,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0005,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0006,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0007,2.6667E+01,1.3119E-01,7.9620E+03,7.0686E-07,0.0000E+00  
 0008,2.6667E+01,1.3119E-01,7.9620E+03,5.6549E-06,0.0000E+00  
 0009,2.6667E+01,1.3119E-01,7.9620E+03,1.1310E-05,0.0000E+00  
 0010,2.6667E+01,1.3119E-01,7.9620E+03,2.2089E-05,0.0000E+00  
 0011,2.6667E+01,1.3119E-01,7.9620E+03,3.7874E-05,0.0000E+00  
 0012,2.6667E+01,1.3119E-01,7.9620E+03,3.2062E-05,0.0000E+00  
 0013,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0014,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0015,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0016,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0017,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0018,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0019,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0020,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0021,2.6667E+01,1.3119E-01,7.9620E+03,1.1781E-07,0.0000E+00  
 0022,2.6667E+01,1.3119E-01,7.9620E+03,9.4248E-07,0.0000E+00  
 0023,2.6667E+01,1.3119E-01,7.9620E+03,1.8850E-06,0.0000E+00  
 0024,2.6667E+01,1.3119E-01,7.9620E+03,3.6816E-06,0.0000E+00  
 0025,2.6667E+01,1.3119E-01,7.9620E+03,6.3813E-06,0.0000E+00  
 0026,2.6667E+01,1.4444E+00,1.2100E-01,1.2284E-07,0.0000E+00  
 0027,2.6667E+01,1.4444E+00,1.2100E-01,9.8269E-07,0.0000E+00  
 0028,2.6667E+01,1.4444E+00,1.2100E-01,1.9654E-06,0.0000E+00  
 0029,2.6667E+01,1.4444E+00,1.2100E-01,3.8386E-06,0.0000E+00  
 0030,2.6667E+01,1.4444E+00,1.2100E-01,2.2003E-06,0.0000E+00  
 0031,2.6667E+01,1.3442E-01,8.0243E+03,6.2832E-08,0.0000E+00  
 0032,2.6667E+01,1.3442E-01,8.0243E+03,5.0265E-07,0.0000E+00  
 0033,2.6667E+01,1.3442E-01,8.0243E+03,1.0053E-06,0.0000E+00  
 0034,2.6667E+01,1.3442E-01,8.0243E+03,1.9635E-06,0.0000E+00  
 0035,2.6667E+01,1.3442E-01,8.0243E+03,2.7614E-06,0.0000E+00  
 0036,2.6667E+01,1.4444E+00,1.2100E-01,9.6785E-09,0.0000E+00  
 0037,2.6667E+01,1.4444E+00,1.2100E-01,7.8478E-07,0.0000E+00  
 0038,2.6667E+01,1.4444E+00,1.2100E-01,5.5139E-06,0.0000E+00  
 0039,2.6667E+01,1.4444E+00,1.2100E-01,2.7842E-05,0.0000E+00  
 0040,2.6667E+01,1.4444E+00,1.2100E-01,6.1178E-05,0.0000E+00

0041,2.6667E+01,1.3442E-01,8.0243E+03,4.0337E-06,0.0000E+00  
 0042,2.6667E+01,1.4444E+00,1.2100E-01,1.4337E-05,0.0000E+00  
 0043,2.6667E+01,1.3119E-01,7.9620E+03,8.7274E-06,0.0000E+00  
 0044,2.6667E+01,1.4444E+00,1.2100E-01,8.8042E-06,0.0000E+00  
 0045,2.6667E+01,1.4444E+00,1.2100E-01,2.9010E-05,0.0000E+00  
 0046,2.6667E+01,1.3119E-01,7.9620E+03,2.6114E-05,0.0000E+00  
 0047,2.6667E+01,1.4444E+00,1.2100E-01,9.6785E-09,0.0000E+00  
 0048,2.6667E+01,1.4444E+00,1.2100E-01,7.8478E-07,0.0000E+00  
 0049,2.6667E+01,1.4444E+00,1.2100E-01,5.5139E-06,0.0000E+00  
 0050,2.6667E+01,1.4444E+00,1.2100E-01,2.7842E-05,0.0000E+00  
 0051,2.6667E+01,1.4444E+00,1.2100E-01,6.5243E-05,0.0000E+00  
 0052,2.6667E+01,1.3442E-01,8.0243E+03,1.0821E-05,0.0000E+00  
 0053,2.6667E+01,1.4444E+00,1.2100E-01,6.5452E-05,0.0000E+00  
 0054,2.6667E+01,1.3119E-01,7.9620E+03,2.2533E-05,0.0000E+00  
 0055,2.6667E+01,1.4444E+00,1.2100E-01,1.5347E-05,0.0000E+00  
 0056,2.6667E+01,1.3119E-01,7.9620E+03,4.7603E-05,0.0000E+00  
 0057,2.6667E+01,1.4444E+00,1.2100E-01,1.6220E-06,0.0000E+00  
 0058,2.6667E+01,1.4444E+00,1.2100E-01,1.2976E-05,0.0000E+00  
 0059,2.6667E+01,1.4444E+00,1.2100E-01,2.5952E-05,0.0000E+00  
 0060,2.6667E+01,1.4444E+00,1.2100E-01,5.0687E-05,0.0000E+00  
 0061,2.6667E+01,1.4444E+00,1.2100E-01,8.1509E-05,0.0000E+00  
 0062,2.6667E+01,1.3442E-01,8.0243E+03,1.0821E-05,0.0000E+00  
 0063,2.6667E+01,1.4444E+00,1.2100E-01,6.5452E-05,0.0000E+00  
 0064,2.6667E+01,1.3119E-01,7.9620E+03,2.2533E-05,0.0000E+00  
 0065,2.6667E+01,1.4444E+00,1.2100E-01,1.5347E-05,0.0000E+00  
 0066,2.6667E+01,1.3119E-01,7.9620E+03,4.7603E-05,0.0000E+00  
 0067,2.6667E+01,1.4444E+00,1.2100E-01,1.3009E-06,0.0000E+00  
 0068,2.6667E+01,1.4444E+00,1.2100E-01,1.0407E-05,0.0000E+00  
 0069,2.6667E+01,1.4444E+00,1.2100E-01,2.0815E-05,0.0000E+00  
 0070,2.6667E+01,1.4444E+00,1.2100E-01,4.0654E-05,0.0000E+00  
 0071,2.6667E+01,1.4444E+00,1.2100E-01,7.0315E-05,0.0000E+00  
 0072,2.6667E+01,1.3442E-01,8.0243E+03,4.7760E-06,0.0000E+00  
 0073,2.6667E+01,1.4444E+00,1.2100E-01,2.0801E-05,0.0000E+00  
 0074,2.6667E+01,1.3119E-01,7.9620E+03,9.0155E-06,0.0000E+00  
 0075,2.6667E+01,1.4444E+00,1.2100E-01,6.1404E-06,0.0000E+00  
 0076,2.6667E+01,1.3119E-01,7.9620E+03,1.9046E-05,0.0000E+00  
 0077,2.6667E+01,1.4444E+00,1.2100E-01,1.4530E-06,0.0000E+00  
 0078,2.6667E+01,1.4444E+00,1.2100E-01,1.1624E-05,0.0000E+00  
 0079,2.6667E+01,1.4444E+00,1.2100E-01,2.3248E-05,0.0000E+00  
 0080,2.6667E+01,1.4444E+00,1.2100E-01,4.5406E-05,0.0000E+00  
 0081,2.6667E+01,1.4444E+00,1.2100E-01,7.4120E-05,0.0000E+00  
 0082,2.6667E+01,1.3442E-01,8.0243E+03,4.2316E-06,0.0000E+00  
 0083,2.6667E+01,1.4444E+00,1.2100E-01,3.1753E-06,0.0000E+00  
 0084,2.6667E+01,1.3442E-01,8.0243E+03,3.9571E-06,0.0000E+00  
 0085,2.6667E+01,1.4444E+00,1.2100E-01,2.2564E-05,0.0000E+00  
 0086,2.6667E+01,1.3119E-01,7.9620E+03,1.0396E-05,0.0000E+00  
 0087,2.6667E+01,1.4444E+00,1.2100E-01,7.0805E-06,0.0000E+00  
 0088,2.6667E+01,1.3119E-01,7.9620E+03,2.1962E-05,0.0000E+00  
 0089,2.6667E+01,1.3442E-01,8.0243E+03,4.7124E-08,0.0000E+00  
 0090,2.6667E+01,1.3442E-01,8.0243E+03,3.7699E-07,0.0000E+00  
 0091,2.6667E+01,1.3442E-01,8.0243E+03,7.5398E-07,0.0000E+00  
 0092,2.6667E+01,1.3442E-01,8.0243E+03,1.4726E-06,0.0000E+00  
 0093,2.6667E+01,1.3442E-01,8.0243E+03,2.5249E-06,0.0000E+00  
 0094,2.6667E+01,1.4444E+00,1.2100E-01,3.2465E-06,0.0000E+00  
 0095,2.6667E+01,1.4444E+00,1.2100E-01,2.5972E-05,0.0000E+00  
 0096,2.6667E+01,1.4444E+00,1.2100E-01,5.1944E-05,0.0000E+00  
 0097,2.6667E+01,1.4444E+00,1.2100E-01,1.0145E-04,0.0000E+00  
 0098,2.6667E+01,1.4444E+00,1.2100E-01,1.7395E-04,0.0000E+00

0099,2.6667E+01,1.4444E+00,1.2100E-01,6.5351E-05,0.0000E+00  
 0100,2.6667E+01,1.3119E-01,7.9620E+03,2.2498E-05,0.0000E+00  
 0101,2.6667E+01,1.4444E+00,1.2100E-01,1.5324E-05,0.0000E+00  
 0102,2.6667E+01,1.3119E-01,7.9620E+03,4.7529E-05,0.0000E+00  
 0103,2.6667E+01,1.4444E+00,1.2100E-01,3.2358E-06,0.0000E+00  
 0104,2.6667E+01,1.4444E+00,1.2100E-01,2.5887E-05,0.0000E+00  
 0105,2.6667E+01,1.4444E+00,1.2100E-01,5.1773E-05,0.0000E+00  
 0106,2.6667E+01,1.4444E+00,1.2100E-01,1.0112E-04,0.0000E+00  
 0107,2.6667E+01,1.4444E+00,1.2100E-01,1.7338E-04,0.0000E+00  
 0108,2.6667E+01,1.4444E+00,1.2100E-01,6.5136E-05,0.0000E+00  
 0109,2.6667E+01,1.3119E-01,7.9620E+03,2.2424E-05,0.0000E+00  
 0110,2.6667E+01,1.4444E+00,1.2100E-01,1.5273E-05,0.0000E+00  
 0111,2.6667E+01,1.3119E-01,7.9620E+03,4.7373E-05,0.0000E+00  
 0112,2.6667E+01,1.3119E-01,7.9620E+03,1.1781E-07,0.0000E+00  
 0113,2.6667E+01,1.3119E-01,7.9620E+03,9.4248E-07,0.0000E+00  
 0114,2.6667E+01,1.3119E-01,7.9620E+03,1.8850E-06,0.0000E+00  
 0115,2.6667E+01,1.3119E-01,7.9620E+03,3.6816E-06,0.0000E+00  
 0116,2.6667E+01,1.3119E-01,7.9620E+03,6.3123E-06,0.0000E+00  
 0117,2.6667E+01,1.3119E-01,7.9620E+03,3.1879E-06,0.0000E+00  
 0118,2.6667E+01,1.3119E-01,7.9620E+03,8.0582E-06,0.0000E+00  
 0119,2.6667E+01,1.4444E+00,1.2100E-01,9.0321E-07,0.0000E+00  
 0120,2.6667E+01,1.4444E+00,1.2100E-01,7.2257E-06,0.0000E+00  
 0121,2.6667E+01,1.4444E+00,1.2100E-01,1.4451E-05,0.0000E+00  
 0122,2.6667E+01,1.4444E+00,1.2100E-01,2.8225E-05,0.0000E+00  
 0123,2.6667E+01,1.4444E+00,1.2100E-01,4.8394E-05,0.0000E+00  
 0124,2.6667E+01,1.4444E+00,1.2100E-01,1.7865E-05,0.0000E+00  
 0125,2.6667E+01,1.4444E+00,1.2100E-01,3.3364E-06,0.0000E+00  
 0126,2.6667E+01,1.3119E-01,7.9620E+03,1.4948E-05,0.0000E+00  
 0127,2.6667E+01,1.3119E-01,7.9620E+03,7.8540E-07,0.0000E+00  
 0128,2.6667E+01,1.3119E-01,7.9620E+03,6.2832E-06,0.0000E+00  
 0129,2.6667E+01,1.3119E-01,7.9620E+03,1.2566E-05,0.0000E+00  
 0130,2.6667E+01,1.3119E-01,7.9620E+03,2.4544E-05,0.0000E+00  
 0131,2.6667E+01,1.3119E-01,7.9620E+03,4.2082E-05,0.0000E+00  
 0132,2.6667E+01,1.3119E-01,7.9620E+03,3.6458E-05,0.0000E+00  
 0133,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0134,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0135,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0136,2.6667E+01,1.4444E+00,1.2100E-01,3.4049E-05,0.0000E+00  
 0137,2.6667E+01,1.4444E+00,1.2100E-01,3.4898E-05,0.0000E+00  
 0138,2.6667E+01,1.4444E+00,1.2100E-01,1.6220E-06,0.0000E+00  
 0139,2.6667E+01,1.4444E+00,1.2100E-01,1.2976E-05,0.0000E+00  
 0140,2.6667E+01,1.4444E+00,1.2100E-01,2.5952E-05,0.0000E+00  
 0141,2.6667E+01,1.4444E+00,1.2100E-01,5.0687E-05,0.0000E+00  
 0142,2.6667E+01,1.4444E+00,1.2100E-01,8.1663E-05,0.0000E+00

COMM

COMM Drum Nodes 143 to 148 (149 to 173 converted to 197 to 221)

COMM

0143,2.6667E+01,1.2506E-01,7.8530E+03,1.9482E-05,0.0000E+00  
 0144,2.6667E+01,1.2506E-01,7.8530E+03,1.9934E-05,0.0000E+00  
 0145,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0146,2.6667E+01,1.2506E-01,7.8530E+03,1.1825E-04,0.0000E+00  
 0147,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0148,2.6667E+01,1.2506E-01,7.8530E+03,5.7100E-05,0.0000E+00

COMM

COMM Lower Button Nodes

COMM

0149,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0150,2.6667E+01,3.9400E-02,1.9860E+04,1.6822E-07,1.1389E-02

0151,2.6667E+01,3.9400E-02,1.9860E+04,6.3841E-07,4.3223E-02  
 0152,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0153,2.6667E+01,3.9400E-02,1.9860E+04,3.3869E-07,2.2931E-02  
 0154,2.6667E+01,3.9400E-02,1.9860E+04,2.7095E-06,1.8345E-01  
 0155,2.6667E+01,3.9400E-02,1.9860E+04,2.7515E-06,1.8629E-01  
 0156,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0157,2.6667E+01,3.9400E-02,1.9860E+04,7.8173E-07,5.2926E-02  
 0158,2.6667E+01,3.9400E-02,1.9860E+04,6.2538E-06,4.2341E-01  
 0159,2.6667E+01,3.9400E-02,1.9860E+04,1.2508E-05,8.4682E-01  
 0160,2.6667E+01,3.9400E-02,1.9860E+04,1.2731E-05,8.6193E-01  
 0161,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0162,2.6667E+01,3.9400E-02,1.9860E+04,1.0042E-06,6.7987E-02  
 0163,2.6667E+01,3.9400E-02,1.9860E+04,8.0334E-06,5.4390E-01  
 0164,2.6667E+01,3.9400E-02,1.9860E+04,1.6067E-05,1.0878E+00  
 0165,2.6667E+01,3.9400E-02,1.9860E+04,3.1380E-05,2.1246E+00  
 0166,2.6667E+01,3.9400E-02,1.9860E+04,1.5411E-05,1.0434E+00  
 0167,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0168,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0169,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0170,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0171,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0172,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

COMM

COMM Upper Button Nodes

COMM

0173,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0174,2.6667E+01,3.9400E-02,1.9860E+04,1.6822E-07,1.1389E-02  
 0175,2.6667E+01,3.9400E-02,1.9860E+04,6.3841E-07,4.3223E-02  
 0176,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0177,2.6667E+01,3.9400E-02,1.9860E+04,3.3869E-07,2.2931E-02  
 0178,2.6667E+01,3.9400E-02,1.9860E+04,2.7095E-06,1.8345E-01  
 0179,2.6667E+01,3.9400E-02,1.9860E+04,2.7515E-06,1.8629E-01  
 0180,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0181,2.6667E+01,3.9400E-02,1.9860E+04,7.8173E-07,5.2926E-02  
 0182,2.6667E+01,3.9400E-02,1.9860E+04,6.2538E-06,4.2341E-01  
 0183,2.6667E+01,3.9400E-02,1.9860E+04,1.2508E-05,8.4682E-01  
 0184,2.6667E+01,3.9400E-02,1.9860E+04,1.2731E-05,8.6193E-01  
 0185,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0186,2.6667E+01,3.9400E-02,1.9860E+04,1.0042E-06,6.7987E-02  
 0187,2.6667E+01,3.9400E-02,1.9860E+04,8.0334E-06,5.4390E-01  
 0188,2.6667E+01,3.9400E-02,1.9860E+04,1.6067E-05,1.0878E+00  
 0189,2.6667E+01,3.9400E-02,1.9860E+04,3.1380E-05,2.1246E+00  
 0190,2.6667E+01,3.9400E-02,1.9860E+04,1.5411E-05,1.0434E+00  
 0191,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0192,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0193,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0194,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0195,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0196,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

COMM

COMM Total Power = 15.000112

COMM

COMM Material Properties

COMM	cp	rho	k	emissivity
COMM	(W.h/kg.K)	(kg/m^3)	(W/m.K)	(-)
COMM SS 316	1.3119E-01	7.9620E+03	1.3650E+01	3.0000E-01
COMM Mild CS	1.2506E-01	7.8530E+03	5.1510E+01	3.0000E-01
COMM Red Paint			4.5000E-01	...

COMM Black Lacquer 8.8000E-01 ...
   
 COMM Concrete 6.3000E-01 ...
   
 COMM White Paint 9.0000E-01 ...
   
 COMM
   
 paint on Aluminum
   
 COMM Air 2.7972E-01 9.0880E-01 2.5810E-02
   
 COMM
   
 COMM Enhancement Factors - conduction represents convection
   
 COMM Enhancement Factor
   
 COMM Vollrath 10
   
 COMM BNFL Inner (open regions only) 5
   
 COMM BNFL Outer (open regions only) 5
   
 COMM Drum 5
   
 COMM Cabinet, side 10
   
 COMM Cabinet, top 2
   
 COMM Bulk Air 1000
   
 COMM
   
 COMM Heat Transfer Coefficients (at 78.2 kPa)
   
 COMM htc (W/m^2.K)
   
 COMM Inside container conduction limited
   
 COMM Container, outside, vertical surface 3.58 revised to a DT=14 K
   
 COMM Container, outside, top 3.70 revised to a DT=10 K
   
 COMM Container, outside, bottom 1.47
   
 COMM Drum, vertical surfaces 1.65
   
 COMM Drum bottom - top surface 1.90
   
 COMM Drum bottom - bottom surface 0.96
   
 COMM Drum top - top surface 1.90
   
 COMM Drum top - bottom surface 1.90
   
 COMM Cabinet walls, vertical 1.41
   
 COMM Cabinet, inside top 1.84
   
 COMM Cabinet, inside bottom 0.62
   
 COMM
   
 COMM Contact HTCs (W/m^2.K) -- resistance = 1/HTC
   
 COMM
   
 COMM Drum inner cylinder to drum top/bottom 1892.75 conductors 524 and 525
   
 COMM Drum top to drum side 1892.75 conductor 526
   
 COMM Drum bottom edge to ? 1892.75 node 156 to ???
   
 COMM Ring 1 Ring 2 Ring 3 Ring 4 Ring 5 ...
   
 COMM BNFL outer bottom to drum 1892.75 1892.75 1892.75 1892.75 1892.75 ...
   
 COMM (conductors 461-466)
   
 COMM Radii (in) Radii (m) ...
   
 COMM Radiation Heat Transfer 2.46062992 0.0625 ...
   
 COMM Effective Emissivity 3.46875 0.08810625 ...
   
 COMM SS 316 & Mild CS 1.7647E-01 3.5 0.0889 ...
   
 COMM SS 316 & Red Paint 2.1951E-01 7 0.1778 ...
   
 COMM Mild CS & Red Paint 2.1951E-01 7.0625 0.1793875 ...
   
 COMM Red Paint/Red Paint 2.9032E-01 ...
   
 COMM Mild CS & Mild CS 1.7647E-01
   
 COMM Black Lacquer/Black Lacquer 7.8571E-01
   
 COMM Black Lacquer/White Paint 8.0162E-01
   
 COMM Black Lacquer/Concrete 5.8016E-01
   
 COMM
   
 COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER
   
 COMM (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)
   
 0197,2.6667E+01,1.2506E-01,7.8530E+03,5.5013E-05,0.0000E+00
   
 0198,2.6667E+01,1.2506E-01,7.8530E+03,6.2363E-05,0.0000E+00
   
 0199,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
   
 0200,2.6667E+01,1.2506E-01,7.8530E+03,3.9416E-05,0.0000E+00

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0201,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0202,2.6667E+01,1.2506E-01,7.8530E+03,1.1825E-04,0.0000E+00
0203,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0204,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0205,2.6667E+01,1.2506E-01,7.8530E+03,3.9591E-05,0.0000E+00
0206,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0207,2.6667E+01,1.2506E-01,7.8530E+03,2.3045E-04,0.0000E+00
0208,2.6667E+01,1.2506E-01,7.8530E+03,2.2203E-04,0.0000E+00
0209,2.6667E+01,1.2506E-01,7.8530E+03,2.5452E-04,0.0000E+00
0210,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
0211,2.6667E+01,2.7972E-01,9.0880E-01,1.5673E-03,0.0000E+00
0212,2.6667E+01,2.7972E-01,9.0880E-01,1.5100E-03,0.0000E+00
0213,2.6667E+01,2.7972E-01,9.0880E-01,1.7118E-03,0.0000E+00
0214,2.6667E+01,2.7972E-01,9.0880E-01,1.7339E-03,0.0000E+00
0215,2.6667E+01,2.7972E-01,9.0880E-01,9.6358E-03,0.0000E+00
0216,2.6667E+01,2.7972E-01,9.0880E-01,9.2836E-03,0.0000E+00
0217,2.6667E+01,2.7972E-01,9.0880E-01,1.0524E-02,0.0000E+00
0218,2.6667E+01,2.7972E-01,9.0880E-01,5.1240E-04,0.0000E+00
0219,2.6667E+01,2.7972E-01,9.0880E-01,1.5372E-03,0.0000E+00

COMM
COMM Air in cabinet and cabinet stainless-steel 304 nodes
COMM
-220,2.9444E+01,2.7972E-01,9.0880E-01,1.3501E-02,0.0000E+00
-221,2.9444E+01,2.7972E-01,9.0880E-01,1.1081E-02,0.0000E+00
-222,2.9444E+01,2.7972E-01,9.0880E-01,1.2702E-02,0.0000E+00
-223,2.9444E+01,2.7972E-01,9.0880E-01,6.4270E-02,0.0000E+00
0224,2.6667E+01,1.3442E-01,8.0243E+03,8.5725E-04,0.0000E+00
0225,2.6667E+01,1.3442E-01,8.0243E+03,2.8869E-04,0.0000E+00
0226,2.6667E+01,1.3442E-01,8.0243E+03,2.3369E-04,0.0000E+00
0227,2.6667E+01,1.3442E-01,8.0243E+03,2.6789E-04,0.0000E+00
0228,2.6667E+01,1.3442E-01,8.0243E+03,6.3845E-04,0.0000E+00

COMM
COMM Boundary temperature node for air outside cabinet
COMM
-229,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
ENDD
COND DMOD
COMM Axial conduction and convection paths for the container
COMM C#, N1, N2, K or H , AREA , DX or 1
COMM (m^2) , (m or -)
0001,0001,0007,1.3650E+01,7.8540E-05,4.5000E-03
0002,0002,0008,1.3650E+01,6.2832E-04,4.5000E-03
0003,0003,0009,1.3650E+01,1.2566E-03,4.5000E-03
0004,0004,0010,1.3650E+01,2.4544E-03,4.5000E-03
0005,0005,0011,1.3650E+01,4.2082E-03,4.5000E-03
0006,0006,0012,1.3650E+01,2.4960E-03,4.5000E-03
0007,0007,0013,1.3650E+01,7.8540E-05,4.5000E-03
0008,0008,0014,1.3650E+01,6.2832E-04,4.5000E-03
0009,0009,0015,1.3650E+01,1.2566E-03,4.5000E-03
0010,0010,0016,1.3650E+01,2.4544E-03,4.5000E-03
0011,0013,0017,1.8928E+03,7.8540E-05,1.0000E+00
0012,0014,0018,1.8928E+03,6.2832E-04,1.0000E+00
0013,0015,0019,1.8928E+03,1.2566E-03,1.0000E+00
0014,0016,0020,1.8928E+03,2.4544E-03,1.0000E+00
0015,0017,0021,1.3650E+01,7.8540E-05,7.5000E-04
0016,0018,0022,1.3650E+01,6.2832E-04,7.5000E-04
0017,0019,0023,1.3650E+01,1.2566E-03,7.5000E-04
0018,0020,0024,1.3650E+01,2.4544E-03,7.5000E-04

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0019,0021,0026,1.5340E-01,7.8540E-05,7.8200E-04  
0020,0022,0027,1.5340E-01,6.2832E-04,7.8200E-04  
0021,0023,0028,1.5340E-01,1.2566E-03,7.8200E-04  
0022,0024,0029,1.5340E-01,2.4544E-03,7.8200E-04  
0023,0025,0030,1.5340E-01,3.8098E-03,2.8877E-04  
0024,0026,0031,1.5340E-01,7.8540E-05,7.8200E-04  
0025,0027,0032,1.5340E-01,6.2832E-04,7.8200E-04  
0026,0028,0033,1.5340E-01,1.2566E-03,7.8200E-04  
0027,0029,0034,1.5340E-01,2.4544E-03,7.8200E-04  
0028,0030,0035,1.5340E-01,2.3089E-03,4.7648E-04  
0029,0031,0133,1.8928E+03,7.8540E-05,1.0000E+00  
0030,0032,0134,1.8928E+03,6.2832E-04,1.0000E+00  
0031,0033,0135,1.8928E+03,1.2566E-03,1.0000E+00  
0032,0133,0036,1.5340E-01,7.8540E-05,6.1615E-05  
0033,0134,0037,1.5340E-01,6.2832E-04,6.2451E-04  
0034,0135,0038,1.5340E-01,1.2566E-03,2.1939E-03  
0035,0034,0039,1.5340E-01,2.4544E-03,5.6718E-03  
0036,0035,0040,1.5340E-01,3.2289E-03,7.9963E-03  
0037,0035,0041,1.5130E+01,2.4686E-04,1.4065E-02  
0038,0030,0042,1.5340E-01,5.5691E-04,1.4847E-02  
0039,0025,0043,1.3650E+01,4.7498E-04,1.5904E-02  
0040,0011,0044,1.5340E-01,4.2082E-03,1.0461E-03  
0041,0012,0045,1.5340E-01,7.0526E-04,2.0567E-02  
0042,0044,0025,1.5340E-01,4.6977E-03,9.3707E-04  
0043,0045,0043,1.5340E-01,5.8455E-03,2.4814E-03  
0044,0012,0046,1.3650E+01,1.3373E-03,1.5000E-02  
0045,0040,0136,7.6700E-01,3.2483E-03,1.4658E-02  
0046,0136,0051,7.6700E-01,3.4584E-03,1.4355E-02  
0047,0051,0137,7.6700E-01,3.4272E-03,1.4610E-02  
0048,0137,0142,7.6700E-01,3.4859E-03,1.6719E-02  
0049,0138,0057,1.5340E+00,7.8540E-05,2.0652E-02  
0050,0041,0052,1.5130E+01,2.6138E-04,2.8416E-02  
0051,0042,0053,1.5340E-01,1.5810E-03,2.5234E-02  
0052,0043,0054,1.3650E+01,5.4428E-04,2.8717E-02  
0053,0045,0055,1.5340E-01,3.7071E-04,3.1200E-02  
0054,0046,0056,1.3650E+01,1.1498E-03,3.1200E-02  
0055,0139,0058,1.5340E+00,6.2832E-04,2.0652E-02  
0056,0140,0059,1.5340E+00,1.2566E-03,2.0652E-02  
0057,0141,0060,1.5340E+00,2.4544E-03,2.0652E-02  
0058,0142,0061,1.5340E+00,3.9468E-03,2.0700E-02  
0059,0057,0067,1.5340E+00,7.8540E-05,1.8608E-02  
0060,0052,0062,1.5130E+01,2.6138E-04,4.1400E-02  
0061,0053,0063,1.5340E-01,1.5810E-03,4.1400E-02  
0062,0054,0064,1.3650E+01,5.4428E-04,4.1400E-02  
0063,0055,0065,1.5340E-01,3.7071E-04,4.1400E-02  
0064,0056,0066,1.3650E+01,1.1498E-03,4.1400E-02  
0065,0058,0068,1.5340E+00,6.2832E-04,1.8608E-02  
0066,0059,0069,1.5340E+00,1.2566E-03,1.8608E-02  
0067,0060,0070,1.5340E+00,2.4544E-03,1.8608E-02  
0068,0061,0071,1.5340E+00,3.9468E-03,1.8608E-02  
0069,0067,0077,1.5340E+00,7.8540E-05,1.7532E-02  
0070,0062,0072,1.5130E+01,2.6138E-04,2.8982E-02  
0071,0063,0073,1.5340E-01,1.5810E-03,2.8982E-02  
0072,0064,0074,1.3650E+01,5.4428E-04,2.8982E-02  
0073,0065,0075,1.5340E-01,3.7071E-04,2.8982E-02  
0074,0066,0076,1.3650E+01,1.1498E-03,2.8982E-02  
0075,0068,0078,1.5340E+00,6.2832E-04,1.7532E-02  
0076,0069,0079,1.5340E+00,1.2566E-03,1.7532E-02

0077,0070,0080,1.5340E+00,2.4544E-03,1.7532E-02  
 0078,0071,0081,1.5340E+00,3.9468E-03,1.7532E-02  
 0079,0078,0090,0.0000E+00,0.0000E+00,9.2500E-03  
 0080,0079,0091,0.0000E+00,0.0000E+00,9.2500E-03  
 0081,0080,0092,0.0000E+00,0.0000E+00,9.2500E-03  
 0082,0081,0093,0.0000E+00,0.0000E+00,9.2500E-03  
 0083,0072,0082,1.5130E+01,2.6138E-04,1.6332E-02  
 0084,0072,0084,1.8928E+03,2.0094E-04,1.0000E+00  
 0085,0073,0085,1.5340E-01,1.2159E-03,1.7832E-02  
 0086,0074,0086,1.3650E+01,5.4428E-04,1.7832E-02  
 0087,0075,0087,1.5340E-01,3.7071E-04,1.7832E-02  
 0088,0076,0088,1.3650E+01,1.1498E-03,1.7832E-02  
 0089,0077,0089,1.5340E-01,7.8540E-05,9.2500E-03  
 0090,0078,0090,1.5340E-01,6.2832E-04,9.2500E-03  
 0091,0079,0091,1.5340E-01,1.2566E-03,9.2500E-03  
 0092,0080,0092,1.5340E-01,2.4544E-03,9.2500E-03  
 0093,0081,0093,1.5340E-01,4.4069E-03,9.2500E-03  
 0094,0084,0093,1.5130E+01,1.9754E-04,1.7300E-02  
 0095,0089,0094,1.5340E-01,7.8540E-05,2.0668E-02  
 0096,0090,0095,1.5340E-01,6.2832E-04,2.0668E-02  
 0097,0091,0096,1.5340E-01,1.2566E-03,2.0668E-02  
 0098,0092,0097,1.5340E-01,2.4544E-03,2.0668E-02  
 0099,0093,0098,1.5340E-01,4.2082E-03,2.0668E-02  
 0100,0084,0099,1.5340E-01,3.9961E-04,2.0668E-02  
 0101,0085,0099,1.5340E-01,1.1814E-03,3.0218E-02  
 0102,0086,0100,1.3650E+01,5.4428E-04,3.0218E-02  
 0103,0087,0101,1.5340E-01,3.7071E-04,3.0218E-02  
 0104,0088,0102,1.3650E+01,1.1498E-03,3.0218E-02  
 0105,0094,0103,7.6700E-01,7.8540E-05,4.1268E-02  
 0106,0095,0104,7.6700E-01,6.2832E-04,4.1268E-02  
 0107,0096,0105,7.6700E-01,1.2566E-03,4.1268E-02  
 0108,0097,0106,7.6700E-01,2.4544E-03,4.1268E-02  
 0109,0098,0107,7.6700E-01,4.2082E-03,4.1268E-02  
 0110,0099,0108,7.6700E-01,1.5810E-03,4.1268E-02  
 0111,0100,0109,1.3650E+01,5.4428E-04,4.1268E-02  
 0112,0101,0110,1.5340E-01,3.7071E-04,4.1268E-02  
 0113,0102,0111,1.3650E+01,1.1498E-03,4.1268E-02  
 0114,0103,0112,1.5340E-01,7.8540E-05,2.0600E-02  
 0115,0104,0113,1.5340E-01,6.2832E-04,2.0600E-02  
 0116,0105,0114,1.5340E-01,1.2566E-03,2.0600E-02  
 0117,0106,0115,1.5340E-01,2.4544E-03,2.0600E-02  
 0118,0107,0116,1.5340E-01,4.2082E-03,2.0600E-02  
 0119,0108,0117,1.5340E-01,1.5810E-03,2.0600E-02  
 0120,0109,0117,1.3650E+01,5.4428E-04,2.1350E-02  
 0121,0110,0125,1.5340E-01,3.7071E-04,2.5100E-02  
 0122,0111,0126,1.3650E+01,1.1498E-03,2.7100E-02  
 0123,0112,0119,1.5340E-01,7.8540E-05,5.7500E-03  
 0124,0113,0120,1.5340E-01,6.2832E-04,5.7500E-03  
 0125,0114,0121,1.5340E-01,1.2566E-03,5.7500E-03  
 0126,0115,0122,1.5340E-01,2.4544E-03,5.7500E-03  
 0127,0116,0123,1.5340E-01,4.2082E-03,5.7500E-03  
 0128,0117,0124,1.5340E-01,1.0508E-03,5.7500E-03  
 0129,0117,0118,1.3650E+01,1.0744E-03,4.5000E-03  
 0130,0118,0124,1.5340E-01,3.6898E-03,2.4209E-03  
 0131,0125,0124,1.5340E-01,3.7071E-04,6.5000E-03  
 0132,0119,0127,1.5340E-01,7.8540E-05,5.7500E-03  
 0133,0120,0128,1.5340E-01,6.2832E-04,5.7500E-03  
 0134,0121,0129,1.5340E-01,1.2566E-03,5.7500E-03

0135,0122,0130,1.5340E-01,2.4544E-03,5.7500E-03  
 0136,0123,0131,1.5340E-01,4.2082E-03,5.7500E-03  
 0137,0124,0132,1.5340E-01,2.4960E-03,5.7500E-03  
 0138,0126,0132,1.3650E+01,1.1498E-03,1.1500E-02  
 COMM  
 COMM Radial conduction and convection paths for the container  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0139,0007,0008,1.3650E+01,2.8274E-04,5.7565E-03  
 0140,0021,0022,1.3650E+01,4.7124E-05,5.7565E-03  
 0141,0026,0027,1.5340E-01,4.9135E-05,5.7565E-03  
 0142,0031,0032,1.5130E+01,2.5133E-05,5.7565E-03  
 0143,0036,0037,1.5340E-01,7.7491E-06,5.7565E-03  
 0144,0047,0048,1.5340E-01,7.7491E-06,5.7565E-03  
 0145,0057,0058,1.5340E+00,6.4880E-04,5.7565E-03  
 0146,0067,0068,1.5340E+00,5.2037E-04,5.7565E-03  
 0147,0077,0078,1.5340E+00,5.8119E-04,5.7565E-03  
 0148,0089,0090,1.5130E+01,1.8850E-05,5.7565E-03  
 0149,0094,0095,7.6700E-01,1.2986E-03,5.7565E-03  
 0150,0103,0104,7.6700E-01,1.2943E-03,5.7565E-03  
 0151,0112,0113,1.3650E+01,4.7124E-05,5.7565E-03  
 0152,0119,0120,7.6700E-01,3.6128E-04,5.7565E-03  
 0153,0127,0128,1.3650E+01,3.1416E-04,5.7565E-03  
 0154,0008,0009,1.3650E+01,8.4823E-04,9.1783E-03  
 0155,0022,0023,1.3650E+01,1.4137E-04,9.1783E-03  
 0156,0027,0028,1.5340E-01,1.4740E-04,9.1783E-03  
 0157,0032,0033,1.5130E+01,7.5398E-05,9.1783E-03  
 0158,0037,0038,3.0680E-01,2.1348E-04,9.1783E-03  
 0159,0048,0049,3.0680E-01,2.1348E-04,9.1783E-03  
 0160,0058,0059,1.5340E+00,1.9464E-03,9.1783E-03  
 0161,0068,0069,1.5340E+00,1.5611E-03,9.1783E-03  
 0162,0078,0079,1.5340E+00,1.7436E-03,9.1783E-03  
 0163,0090,0091,1.5130E+01,5.6549E-05,9.1783E-03  
 0164,0095,0096,7.6700E-01,3.8958E-03,9.1783E-03  
 0165,0104,0105,7.6700E-01,3.8830E-03,9.1783E-03  
 0166,0113,0114,1.3650E+01,1.4137E-04,9.1783E-03  
 0167,0120,0121,7.6700E-01,1.0838E-03,9.1783E-03  
 0168,0128,0129,1.3650E+01,9.4248E-04,9.1783E-03  
 0169,0009,0010,1.3650E+01,1.4137E-03,1.0890E-02  
 0170,0023,0024,1.3650E+01,2.3562E-04,1.0890E-02  
 0171,0028,0029,1.5340E-01,2.4567E-04,1.0890E-02  
 0172,0033,0034,1.5130E+01,1.2566E-04,1.0890E-02  
 0173,0038,0039,4.6020E-01,1.0332E-03,1.0890E-02  
 0174,0049,0050,4.6020E-01,1.0332E-03,1.0890E-02  
 0175,0059,0060,1.5340E+00,3.2440E-03,1.0890E-02  
 0176,0069,0070,1.5340E+00,2.6019E-03,1.0890E-02  
 0177,0079,0080,1.5340E+00,2.9060E-03,1.0890E-02  
 0178,0138,0139,1.5340E+00,6.4880E-04,5.7565E-03  
 0179,0139,0140,1.5340E+00,1.9464E-03,9.1783E-03  
 0180,0140,0141,1.5340E+00,3.2440E-03,1.0890E-02  
 0181,0141,0142,1.5340E+00,4.8660E-03,1.3026E-02  
 0182,0091,0092,1.5130E+01,9.4248E-05,1.0890E-02  
 0183,0096,0097,7.6700E-01,6.4930E-03,1.0890E-02  
 0184,0105,0106,7.6700E-01,6.4717E-03,1.0890E-02  
 0185,0114,0115,1.3650E+01,2.3562E-04,1.0890E-02  
 0186,0121,0122,7.6700E-01,1.8064E-03,1.0890E-02  
 0187,0129,0130,1.3650E+01,1.5708E-03,1.0890E-02  
 0188,0010,0011,1.3650E+01,2.1206E-03,1.3405E-02

0189,0024,0025,1.3650E+01,3.5343E-04,1.3405E-02  
 0190,0029,0030,1.5340E-01,2.2525E-04,1.3405E-02  
 0191,0034,0035,1.5130E+01,1.8850E-04,1.3405E-02  
 0192,0039,0040,7.6700E-01,3.8949E-03,1.3026E-02  
 0193,0050,0051,7.6700E-01,3.8949E-03,1.3026E-02  
 0194,0060,0061,1.5340E+00,4.8660E-03,1.3026E-02  
 0195,0070,0071,1.5340E+00,3.9028E-03,1.3026E-02  
 0196,0080,0081,1.5340E+00,4.3590E-03,1.3026E-02  
 0197,0092,0093,1.5130E+01,1.4137E-04,1.3405E-02  
 0198,0097,0098,7.6700E-01,9.7396E-03,1.3405E-02  
 0199,0106,0107,7.6700E-01,9.7075E-03,1.3405E-02  
 0200,0115,0116,1.3650E+01,3.5343E-04,1.3405E-02  
 0201,0122,0123,7.6700E-01,2.7096E-03,1.3405E-02  
 0202,0130,0131,1.3650E+01,2.3562E-03,1.3405E-02  
 0203,0040,0041,1.5340E-01,5.0293E-03,6.2610E-03  
 0204,0051,0052,1.5340E-01,5.3594E-03,6.9424E-03  
 0205,0061,0062,1.5340E-01,6.6956E-03,6.9424E-03  
 0206,0071,0072,1.5340E-01,5.3703E-03,6.9424E-03  
 0207,0081,0082,1.5340E-01,5.2198E-03,6.9424E-03  
 0208,0041,0042,1.5340E-01,5.0579E-03,1.2063E-03  
 0209,0052,0053,1.5340E-01,1.3630E-02,2.2972E-03  
 0210,0062,0063,1.5340E-01,1.3630E-02,2.2972E-03  
 0211,0072,0073,1.5340E-01,5.4535E-03,2.2972E-03  
 0212,0082,0083,1.5340E-01,5.3007E-03,2.9999E-04  
 0213,0083,0084,1.5340E-01,5.3614E-03,2.9999E-04  
 0214,0081,0084,1.5340E-01,7.9922E-04,7.6126E-03  
 0215,0084,0085,1.5340E-01,6.4325E-03,1.6989E-03  
 0216,0098,0099,7.6700E-01,1.3609E-02,9.6231E-03  
 0217,0107,0108,7.6700E-01,1.3565E-02,9.6231E-03  
 0218,0042,0043,1.5340E-01,5.7965E-03,1.0910E-03  
 0219,0053,0054,1.5340E-01,1.4827E-02,2.2973E-03  
 0220,0063,0064,1.5340E-01,1.4827E-02,2.2973E-03  
 0221,0073,0074,1.5340E-01,5.9323E-03,2.2973E-03  
 0222,0085,0086,1.5340E-01,6.8405E-03,1.6989E-03  
 0223,0099,0100,1.5340E-01,1.4804E-02,2.2973E-03  
 0224,0108,0109,1.5340E-01,1.4755E-02,2.2973E-03  
 0225,0116,0117,1.3650E+01,5.3721E-04,1.0370E-02  
 0226,0044,0045,1.5340E-01,2.8740E-03,6.5787E-03  
 0227,0054,0055,1.5340E-01,1.5217E-02,4.9998E-04  
 0228,0064,0065,1.5340E-01,1.5217E-02,4.9998E-04  
 0229,0074,0075,1.5340E-01,6.0884E-03,4.9998E-04  
 0230,0086,0087,1.5340E-01,7.0205E-03,4.9998E-04  
 0231,0100,0101,1.5340E-01,1.5194E-02,4.9998E-04  
 0232,0109,0110,1.5340E-01,1.5144E-02,4.9998E-04  
 0233,0117,0125,1.5340E-01,5.5135E-04,4.9998E-04  
 0234,0118,0125,1.5340E-01,3.7498E-06,4.9998E-04  
 0235,0123,0124,7.6700E-01,3.7862E-03,9.5848E-03  
 0236,0011,0012,1.3650E+01,2.9632E-03,1.2349E-02  
 0237,0045,0046,1.5340E-01,8.8281E-03,3.8220E-03  
 0238,0055,0056,1.5340E-01,1.5477E-02,4.9998E-04  
 0239,0065,0066,1.5340E-01,1.5477E-02,4.9998E-04  
 0240,0075,0076,1.5340E-01,6.1924E-03,4.9998E-04  
 0241,0087,0088,1.5340E-01,7.1405E-03,4.9998E-04  
 0242,0101,0102,1.5340E-01,1.5453E-02,4.9998E-04  
 0243,0110,0111,1.5340E-01,1.5403E-02,4.9998E-04  
 0244,0125,0126,1.5340E-01,3.3646E-03,4.9998E-04  
 0245,0124,0126,1.5340E-01,1.4954E-03,3.5408E-03  
 0246,0131,0132,1.3650E+01,3.7385E-03,1.2349E-02

COMM  
 COMM Radiation paths for the container  
 COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT  
 COMM (m<sup>2</sup>) , (-)  
 -247,0021,0031,1.7647E-01,7.8540E-05,1.0000E+00  
 -248,0022,0032,1.7647E-01,6.2832E-04,1.0000E+00  
 -249,0023,0033,1.7647E-01,1.2566E-03,1.0000E+00  
 -250,0024,0034,1.7647E-01,2.4544E-03,1.0000E+00  
 -251,0025,0035,1.7647E-01,3.8098E-03,1.0000E+00  
 -252,0025,0011,1.7647E-01,4.6977E-03,1.0000E+00  
 -253,0043,0046,1.7647E-01,5.8455E-03,1.0000E+00  
 -254,0054,0056,1.7647E-01,1.5217E-02,1.0000E+00  
 -255,0064,0066,1.7647E-01,1.5217E-02,1.0000E+00  
 -256,0074,0076,1.7647E-01,6.0884E-03,1.0000E+00  
 -257,0086,0088,1.7647E-01,7.0205E-03,1.0000E+00  
 -258,0100,0102,1.7647E-01,1.5194E-02,1.0000E+00  
 -259,0109,0111,1.7647E-01,1.5144E-02,1.0000E+00  
 -260,0117,0126,1.7647E-01,5.5135E-04,1.0000E+00  
 -261,0118,0126,1.7647E-01,3.7498E-06,1.0000E+00  
 -262,0082,0084,1.7647E-01,5.3007E-03,1.0000E+00  
 COMM  
 COMM Revised radiation paths for the Vollrath interior  
 COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT  
 COMM (m<sup>2</sup>) , (-)  
 -263,0133,0149,2.3077E-01,7.8540E-05,1.0000E+00  
 -264,0134,0152,2.3077E-01,6.2832E-04,8.5165E-01  
 -265,0134,0156,2.3077E-01,6.2832E-04,8.1170E-02  
 -266,0134,0041,1.7647E-01,6.2832E-04,6.7180E-02  
 -267,0135,0152,2.3077E-01,1.2566E-03,6.7710E-02  
 -268,0135,0156,2.3077E-01,1.2566E-03,6.3676E-01  
 -269,0135,0161,2.3077E-01,1.2566E-03,9.5370E-02  
 -270,0135,0041,1.7647E-01,1.2566E-03,1.1091E-01  
 -271,0135,0052,1.7647E-01,1.2566E-03,8.9250E-02  
 -272,0034,0156,2.3077E-01,2.4544E-03,1.4773E-01  
 -273,0034,0161,2.3077E-01,2.4544E-03,4.2200E-01  
 -274,0034,0167,2.3077E-01,2.4544E-03,4.6790E-02  
 -275,0034,0041,1.7647E-01,2.4544E-03,1.9010E-01  
 -276,0034,0052,1.7647E-01,2.4544E-03,1.9338E-01  
 -277,0035,0156,2.3077E-01,3.2289E-03,1.6030E-02  
 -278,0035,0161,2.3077E-01,3.2289E-03,2.1478E-01  
 -279,0035,0167,2.3077E-01,3.2289E-03,1.6497E-01  
 -280,0035,0041,1.7647E-01,3.2289E-03,4.0641E-01  
 -281,0035,0052,1.7647E-01,3.2289E-03,1.7892E-01  
 -282,0035,0062,1.7647E-01,3.2289E-03,1.8890E-02  
 -283,0041,0156,2.3077E-01,5.0293E-03,2.3440E-02  
 -284,0041,0161,2.3077E-01,5.0293E-03,1.8463E-01  
 -285,0041,0167,2.3077E-01,5.0293E-03,2.2441E-01  
 -286,0041,0052,1.7647E-01,5.0293E-03,5.4950E-02  
 -287,0041,0093,1.7647E-01,5.0293E-03,6.1800E-03  
 -288,0041,0191,2.3077E-01,5.0293E-03,1.0530E-02  
 -289,0052,0161,2.3077E-01,1.3422E-02,1.1320E-02  
 -290,0052,0167,2.3077E-01,1.3422E-02,1.5339E-01  
 -291,0168,0173,3.3333E-01,7.8540E-05,1.0000E+00  
 -292,0169,0176,3.3333E-01,6.2832E-04,8.5162E-01  
 -293,0169,0180,3.3333E-01,6.2832E-04,8.1160E-02  
 -294,0169,0052,2.3077E-01,6.2832E-04,6.7220E-02  
 -295,0170,0176,3.3333E-01,1.2566E-03,6.7540E-02  
 -296,0170,0180,3.3333E-01,1.2566E-03,6.3521E-01

-297,0170,0185,3.3333E-01,1.2566E-03,9.5140E-02  
 -298,0170,0052,2.3077E-01,1.2566E-03,2.0211E-01  
 -299,0171,0180,3.3333E-01,2.4544E-03,1.4653E-01  
 -300,0171,0185,3.3333E-01,2.4544E-03,4.1861E-01  
 -301,0171,0191,3.3333E-01,2.4544E-03,4.6410E-02  
 -302,0171,0052,2.3077E-01,2.4544E-03,3.2969E-01  
 -303,0171,0062,2.3077E-01,2.4544E-03,5.8760E-02  
 -304,0172,0180,3.3333E-01,2.2394E-03,2.1210E-02  
 -305,0172,0185,3.3333E-01,2.2394E-03,2.6871E-01  
 -306,0172,0191,3.3333E-01,2.2394E-03,1.5419E-01  
 -307,0172,0052,2.3077E-01,2.2394E-03,4.6630E-01  
 -308,0172,0062,2.3077E-01,2.2394E-03,8.9590E-02  
 -309,0052,0180,2.3077E-01,1.3422E-02,1.0800E-02  
 -310,0052,0185,2.3077E-01,1.3422E-02,1.0666E-01  
 -311,0052,0191,2.3077E-01,1.3422E-02,2.4576E-01  
 -312,0052,0062,1.7647E-01,1.3422E-02,8.7900E-03  
 -313,0192,0062,2.3077E-01,7.8540E-05,3.9298E-01  
 -314,0192,0072,2.3077E-01,7.8540E-05,1.6588E-01  
 -315,0192,0082,2.3077E-01,7.8540E-05,1.2882E-01  
 -316,0192,0093,2.3077E-01,7.8540E-05,1.1892E-01  
 -317,0192,0092,2.3077E-01,7.8540E-05,9.7130E-02  
 -318,0192,0091,2.3077E-01,7.8540E-05,5.9350E-02  
 -319,0192,0090,2.3077E-01,7.8540E-05,3.6920E-02  
 -320,0193,0062,2.3077E-01,6.2832E-04,4.0535E-01  
 -321,0193,0072,2.3077E-01,6.2832E-04,1.6266E-01  
 -322,0193,0082,2.3077E-01,6.2832E-04,1.2528E-01  
 -323,0193,0093,2.3077E-01,6.2832E-04,1.1805E-01  
 -324,0193,0092,2.3077E-01,6.2832E-04,9.5330E-02  
 -325,0193,0091,2.3077E-01,6.2832E-04,5.7680E-02  
 -326,0193,0090,2.3077E-01,6.2832E-04,3.5650E-02  
 -327,0194,0062,2.3077E-01,1.2566E-03,4.3923E-01  
 -328,0194,0072,2.3077E-01,1.2566E-03,1.5287E-01  
 -329,0194,0082,2.3077E-01,1.2566E-03,1.1578E-01  
 -330,0194,0093,2.3077E-01,1.2566E-03,1.1549E-01  
 -331,0194,0092,2.3077E-01,1.2566E-03,9.0580E-02  
 -332,0194,0091,2.3077E-01,1.2566E-03,5.3510E-02  
 -333,0194,0090,2.3077E-01,1.2566E-03,3.2540E-02  
 -334,0195,0062,2.3077E-01,2.4544E-03,5.0786E-01  
 -335,0195,0072,2.3077E-01,2.4544E-03,1.2954E-01  
 -336,0195,0082,2.3077E-01,2.4544E-03,9.7340E-02  
 -337,0195,0093,2.3077E-01,2.4544E-03,1.0968E-01  
 -338,0195,0092,2.3077E-01,2.4544E-03,8.1710E-02  
 -339,0195,0091,2.3077E-01,2.4544E-03,4.6370E-02  
 -340,0195,0090,2.3077E-01,2.4544E-03,2.7500E-02  
 -341,0196,0062,2.3077E-01,2.2394E-03,5.9370E-01

COMM

COMM End revised radiation paths for the Vollrath interior  
COMM

-342,0084,0074,1.7647E-01,6.4325E-03,7.5010E-02  
 -343,0084,0086,1.7647E-01,6.4325E-03,8.5000E-01  
 -344,0084,0100,1.7647E-01,6.4325E-03,7.4990E-02  
 -345,0072,0064,1.7647E-01,5.4535E-03,1.1177E-01  
 -346,0072,0074,1.7647E-01,5.4535E-03,7.7646E-01  
 -347,0072,0086,1.7647E-01,5.4535E-03,1.1177E-01  
 -348,0062,0054,1.7647E-01,1.3630E-02,4.7040E-02  
 -349,0062,0064,1.7647E-01,1.3630E-02,9.0593E-01  
 -350,0062,0074,1.7647E-01,1.3630E-02,4.7030E-02  
 -351,0052,0043,1.7647E-01,1.3630E-02,4.7030E-02

-352,0052,0054,1.7647E-01,1.3630E-02,9.0594E-01  
-353,0052,0064,1.7647E-01,1.3630E-02,4.7030E-02  
-354,0041,0025,1.7647E-01,5.6418E-03,9.6800E-02  
-355,0041,0043,1.7647E-01,5.6418E-03,8.0688E-01  
-356,0041,0054,1.7647E-01,5.6418E-03,9.6320E-02  
-357,0025,0043,1.7647E-01,1.5810E-03,5.0163E-01  
-358,0025,0054,1.7647E-01,1.5810E-03,6.8780E-02  
-359,0025,0064,1.7647E-01,1.5810E-03,1.8250E-02  
-360,0043,0054,1.7647E-01,6.9838E-03,2.4620E-02  
-361,0054,0064,1.7647E-01,1.4827E-02,1.5880E-02  
-362,0064,0074,1.7647E-01,1.4827E-02,1.6030E-02  
-363,0074,0086,1.7647E-01,5.9323E-03,2.7450E-02  
-364,0086,0100,1.7647E-01,6.8405E-03,7.2530E-02  
-365,0089,0100,1.7647E-01,7.8540E-05,3.4583E-01  
-366,0089,0109,1.7647E-01,7.8540E-05,3.3180E-01  
-367,0089,0117,1.7647E-01,7.8540E-05,3.5640E-02  
-368,0089,0116,1.7647E-01,7.8540E-05,1.1606E-01  
-369,0089,0115,1.7647E-01,7.8540E-05,8.6900E-02  
-370,0089,0114,1.7647E-01,7.8540E-05,5.1920E-02  
-371,0089,0113,1.7647E-01,7.8540E-05,3.1850E-02  
-372,0090,0100,1.7647E-01,6.2832E-04,3.5624E-01  
-373,0090,0109,1.7647E-01,6.2832E-04,3.2624E-01  
-374,0090,0117,1.7647E-01,6.2832E-04,3.5560E-02  
-375,0090,0116,1.7647E-01,6.2832E-04,1.1510E-01  
-376,0090,0115,1.7647E-01,6.2832E-04,8.5360E-02  
-377,0090,0114,1.7647E-01,6.2832E-04,5.0610E-02  
-378,0090,0113,1.7647E-01,6.2832E-04,3.0890E-02  
-379,0091,0100,1.7647E-01,1.2566E-03,3.8497E-01  
-380,0091,0109,1.7647E-01,1.2566E-03,3.1014E-01  
-381,0091,0117,1.7647E-01,1.2566E-03,3.5280E-02  
-382,0091,0116,1.7647E-01,1.2566E-03,1.1240E-01  
-383,0091,0115,1.7647E-01,1.2566E-03,8.1340E-02  
-384,0091,0114,1.7647E-01,1.2566E-03,4.7320E-02  
-385,0091,0113,1.7647E-01,1.2566E-03,2.8550E-02  
-386,0092,0100,1.7647E-01,2.4544E-03,4.4490E-01  
-387,0092,0109,1.7647E-01,2.4544E-03,2.7379E-01  
-388,0092,0117,1.7647E-01,2.4544E-03,3.4480E-02  
-389,0092,0116,1.7647E-01,2.4544E-03,1.0666E-01  
-390,0092,0115,1.7647E-01,2.4544E-03,7.3900E-02  
-391,0092,0114,1.7647E-01,2.4544E-03,4.1650E-02  
-392,0092,0113,1.7647E-01,2.4544E-03,2.4620E-02  
-393,0093,0100,1.7647E-01,4.6078E-03,5.6253E-01  
-394,0093,0109,1.7647E-01,4.6078E-03,1.9631E-01  
-395,0093,0117,1.7647E-01,4.6078E-03,3.2270E-02  
-396,0093,0116,1.7647E-01,4.6078E-03,9.5060E-02  
-397,0093,0115,1.7647E-01,4.6078E-03,6.1570E-02  
-398,0093,0114,1.7647E-01,4.6078E-03,3.3160E-02  
-399,0093,0113,1.7647E-01,4.6078E-03,1.9100E-02  
-400,0100,0109,1.7647E-01,1.4804E-02,1.9056E-01  
-401,0100,0117,1.7647E-01,1.4755E-02,1.4840E-02  
-402,0100,0116,1.7647E-01,5.3721E-04,5.7330E-02  
-403,0100,0115,1.7647E-01,2.8740E-03,4.5610E-02  
-404,0100,0114,1.7647E-01,1.5217E-02,2.6450E-02  
-405,0100,0113,1.7647E-01,1.5217E-02,1.5680E-02  
-406,0109,0117,1.7647E-01,1.4755E-02,6.9410E-02  
-407,0109,0116,1.7647E-01,1.4755E-02,1.5831E-01  
-408,0109,0115,1.7647E-01,1.4755E-02,7.3760E-02  
-409,0109,0114,1.7647E-01,1.4755E-02,3.2650E-02

-410,0109,0113,1.7647E-01,1.4755E-02,1.6930E-02  
-411,0112,0118,1.7647E-01,7.8540E-05,1.8050E-02  
-412,0112,0126,1.7647E-01,7.8540E-05,2.2210E-02  
-413,0112,0132,1.7647E-01,7.8540E-05,6.9300E-03  
-414,0112,0131,1.7647E-01,7.8540E-05,4.0830E-02  
-415,0112,0130,1.7647E-01,7.8540E-05,9.2010E-02  
-416,0112,0129,1.7647E-01,7.8540E-05,2.0665E-01  
-417,0112,0128,1.7647E-01,7.8540E-05,4.7301E-01  
-418,0112,0127,1.7647E-01,7.8540E-05,1.4031E-01  
-419,0113,0118,1.7647E-01,6.2832E-04,1.9420E-02  
-420,0113,0126,1.7647E-01,6.2832E-04,2.3670E-02  
-421,0113,0132,1.7647E-01,6.2832E-04,7.9600E-03  
-422,0113,0131,1.7647E-01,6.2832E-04,5.0320E-02  
-423,0113,0130,1.7647E-01,6.2832E-04,1.3181E-01  
-424,0113,0129,1.7647E-01,6.2832E-04,3.1154E-01  
-425,0113,0128,1.7647E-01,6.2832E-04,3.9613E-01  
-426,0113,0127,1.7647E-01,6.2832E-04,5.9150E-02  
-427,0114,0118,1.7647E-01,1.2566E-03,2.3910E-02  
-428,0114,0126,1.7647E-01,1.2566E-03,2.8250E-02  
-429,0114,0132,1.7647E-01,1.2566E-03,1.1650E-02  
-430,0114,0131,1.7647E-01,1.2566E-03,8.9090E-02  
-431,0114,0130,1.7647E-01,1.2566E-03,2.9233E-01  
-432,0114,0129,1.7647E-01,1.2566E-03,3.8614E-01  
-433,0114,0128,1.7647E-01,1.2566E-03,1.5572E-01  
-434,0114,0127,1.7647E-01,1.2566E-03,1.2910E-02  
-435,0115,0118,1.7647E-01,2.4544E-03,3.9180E-02  
-436,0115,0126,1.7647E-01,2.4544E-03,3.9320E-02  
-437,0115,0132,1.7647E-01,2.4544E-03,2.6240E-02  
-438,0115,0131,1.7647E-01,2.4544E-03,2.6346E-01  
-439,0115,0130,1.7647E-01,2.4544E-03,4.4540E-01  
-440,0115,0129,1.7647E-01,2.4544E-03,1.4971E-01  
-441,0115,0128,1.7647E-01,2.4544E-03,3.6690E-02  
-442,0116,0118,1.7647E-01,4.2082E-03,1.4882E-01  
-443,0116,0126,1.7647E-01,4.2082E-03,5.5580E-02  
-444,0116,0132,1.7647E-01,4.2082E-03,1.1159E-01  
-445,0116,0131,1.7647E-01,4.2082E-03,4.9531E-01  
-446,0116,0130,1.7647E-01,4.2082E-03,1.5378E-01  
-447,0116,0129,1.7647E-01,4.2082E-03,3.4920E-02  
-448,0117,0118,1.7647E-01,1.0508E-03,4.3510E-01  
-449,0117,0126,1.7647E-01,1.0508E-03,1.0350E-02  
-450,0117,0132,1.7647E-01,1.0508E-03,1.7494E-01  
-451,0117,0131,1.7647E-01,1.0508E-03,3.2188E-01  
-452,0117,0130,1.7647E-01,1.0508E-03,4.4180E-02  
-453,0117,0129,1.7647E-01,1.0508E-03,1.3550E-02  
-454,0118,0126,1.7647E-01,1.4954E-03,2.0720E-02  
-455,0118,0132,1.7647E-01,2.6154E-03,4.8040E-02  
-456,0118,0131,1.7647E-01,2.6154E-03,2.1840E-01  
-457,0118,0130,1.7647E-01,2.6154E-03,5.4060E-02  
-458,0118,0129,1.7647E-01,2.6154E-03,1.8370E-02  
-459,0118,0128,1.7647E-01,2.6154E-03,8.4400E-03  
-460,0118,0126,1.7647E-01,1.0744E-03,3.1006E-01  
-461,0118,0132,1.7647E-01,1.0744E-03,5.8899E-01  
-462,0118,0131,1.7647E-01,1.0744E-03,1.0095E-01  
-463,0126,0132,1.7647E-01,1.4954E-03,3.7720E-01  
-464,0126,0131,1.7647E-01,1.4954E-03,8.5330E-02  
-465,0126,0130,1.7647E-01,1.4954E-03,2.1880E-02

COMM

COMM Contact resistances between bottom of container and drum bottom

COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0466,0001,0143,1.8928E+03,7.8540E-05,1.0000E+00  
 0467,0002,0143,1.8928E+03,6.2832E-04,1.0000E+00  
 0468,0003,0143,1.8928E+03,1.2566E-03,1.0000E+00  
 0469,0004,0143,1.8928E+03,2.4544E-03,1.0000E+00  
 0470,0005,0143,1.8928E+03,4.2082E-03,1.0000E+00  
 0471,0006,0143,1.8928E+03,3.6458E-03,1.0000E+00  
 COMM  
 COMM Radial convection paths between container side and drum gas  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0472,0012,0211,3.5800E+00,3.5343E-03,1.0000E+00  
 0473,0046,0211,3.5800E+00,8.2467E-03,1.0000E+00  
 0474,0056,0211,3.5800E+00,1.6258E-02,1.0000E+00  
 0475,0066,0211,3.5800E+00,1.6258E-02,1.0000E+00  
 0476,0076,0211,3.5800E+00,6.5047E-03,1.0000E+00  
 0477,0088,0212,3.5800E+00,7.5006E-03,1.0000E+00  
 0478,0102,0212,3.5800E+00,1.6233E-02,1.0000E+00  
 0479,0111,0212,3.5800E+00,1.6179E-02,1.0000E+00  
 0480,0126,0212,3.5800E+00,5.1051E-03,1.0000E+00  
 0481,0132,0212,3.5800E+00,3.9270E-03,1.0000E+00  
 COMM  
 COMM Axial convection paths between container top and drum gas  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0482,0132,0214,3.7000E+00,3.6458E-03,1.0000E+00  
 0483,0131,0214,3.7000E+00,4.2082E-03,1.0000E+00  
 0484,0130,0214,3.7000E+00,2.4544E-03,1.0000E+00  
 0485,0129,0214,3.7000E+00,1.2566E-03,1.0000E+00  
 0486,0128,0214,3.7000E+00,6.2832E-04,1.0000E+00  
 0487,0127,0214,3.7000E+00,7.8540E-05,1.0000E+00  
 COMM  
 COMM Radial convection paths between drum inner gas and inside of cylinder  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0488,0211,0148,1.6500E+00,7.1614E-02,1.0000E+00  
 0489,0212,0197,1.6500E+00,6.8997E-02,1.0000E+00  
 0490,0213,0198,1.6500E+00,7.8215E-02,1.0000E+00  
 COMM  
 COMM Radial convection paths between outside of cylinder and drum outer gas  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0491,0148,0215,1.6500E+00,7.2260E-02,1.0000E+00  
 0492,0197,0216,1.6500E+00,6.9619E-02,1.0000E+00  
 0493,0198,0217,1.6500E+00,7.8920E-02,1.0000E+00  
 COMM  
 COMM Radial convection paths between drum outer gas and inside of drum side  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)  
 0494,0219,0205,1.6500E+00,2.3055E-02,1.0000E+00  
 0495,0215,0207,1.6500E+00,1.4452E-01,1.0000E+00  
 0496,0216,0208,1.6500E+00,1.3924E-01,1.0000E+00  
 0497,0217,0209,1.6500E+00,1.5784E-01,1.0000E+00  
 COMM  
 COMM Axial convection paths between drum gas and drum top and bottom  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m<sup>2</sup>) , (m or -)

0498,0218,0143,9.6000E-01,1.2272E-02,1.0000E+00  
 0499,0218,0144,9.6000E-01,1.2557E-02,1.0000E+00  
 0500,0219,0146,9.6000E-01,7.4486E-02,1.0000E+00  
 0501,0144,0211,1.9000E+00,1.2115E-02,1.0000E+00  
 0502,0146,0215,1.9000E+00,7.4486E-02,1.0000E+00  
 0503,0214,0200,1.9000E+00,1.2272E-02,1.0000E+00  
 0504,0213,0200,1.9000E+00,1.2115E-02,1.0000E+00  
 0505,0217,0202,1.9000E+00,7.4486E-02,1.0000E+00  
 COMM  
 COMM Radial conduction paths between gas nodes  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0506,0218,0219,1.2905E-01,1.1528E-02,7.1540E-02  
 0507,0214,0213,1.2905E-01,5.5483E-02,3.4199E-02  
 COMM  
 COMM Axial conduction paths between gas nodes  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0508,0211,0212,1.2905E-01,1.2115E-02,1.2700E-01  
 0509,0212,0213,1.2905E-01,1.2115E-02,1.3296E-01  
 0510,0215,0216,1.2905E-01,7.4486E-02,1.2700E-01  
 0511,0216,0217,1.2905E-01,7.4486E-02,1.3296E-01  
 COMM  
 COMM Radial conduction paths between metal nodes  
 COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0512,0143,0144,5.1510E+01,6.2341E-04,3.4573E-02  
 0513,0144,0145,5.1510E+01,8.8674E-04,1.2958E-02  
 0514,0145,0146,5.1510E+01,8.8674E-04,4.0729E-02  
 0515,0146,0206,5.1510E+01,1.7735E-03,4.2577E-02  
 0516,0200,0201,5.1510E+01,8.8674E-04,3.0810E-02  
 0517,0201,0202,5.1510E+01,8.8674E-04,4.0729E-02  
 0518,0202,0203,5.1510E+01,1.7735E-03,4.1783E-02  
 COMM  
 COMM Axial conduction paths between metal nodes  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0519,0147,0148,5.1510E+01,4.4139E-04,6.4682E-02  
 0520,0148,0197,5.1510E+01,4.4139E-04,1.2700E-01  
 0521,0197,0198,5.1510E+01,4.4139E-04,1.3296E-01  
 0522,0198,0199,5.1510E+01,4.4139E-04,7.0644E-02  
 0523,0204,0205,5.1510E+01,1.7814E-03,1.0716E-02  
 0524,0205,0206,5.1510E+01,1.7814E-03,1.0716E-02  
 0525,0206,0207,5.1510E+01,1.7814E-03,6.5079E-02  
 0526,0207,0208,5.1510E+01,1.7814E-03,1.2740E-01  
 0527,0208,0209,5.1510E+01,1.7814E-03,1.3376E-01  
 0528,0209,0210,5.1510E+01,1.7814E-03,7.1438E-02  
 COMM  
 COMM Contact resistances within the drum  
 COMM C#, N1, N2, K or H , AREA , DX or 1  
 COMM (m^2) , (m or -)  
 0529,0145,0147,1.8928E+03,4.4139E-04,1.0000E+00  
 0530,0199,0201,1.8928E+03,4.4139E-04,1.0000E+00  
 0531,0203,0210,1.8928E+03,9.0653E-03,1.0000E+00  
 COMM  
 COMM Radiation paths inside the drum  
 COMM C#, N1, N2, Emissivity, AREA , VIEW FACT  
 COMM (m^2) , ( - )

-532,0127,0198,1.7647E-01,7.8540E-05,7.2022E-01  
 -533,0127,0200,2.1951E-01,7.8540E-05,2.7978E-01  
 -534,0128,0198,1.7647E-01,6.2832E-04,7.2185E-01  
 -535,0128,0200,2.1951E-01,6.2832E-04,2.7815E-01  
 -536,0129,0198,1.7647E-01,1.2566E-03,7.2615E-01  
 -537,0129,0200,2.1951E-01,1.2566E-03,2.7385E-01  
 -538,0130,0198,1.7647E-01,2.4544E-03,7.3443E-01  
 -539,0130,0200,2.1951E-01,2.4544E-03,2.6557E-01  
 -540,0131,0198,1.7647E-01,4.2082E-03,7.4868E-01  
 -541,0131,0200,2.1951E-01,4.2082E-03,2.5132E-01  
 -542,0132,0198,1.7647E-01,3.6458E-03,7.6456E-01  
 -543,0132,0200,2.1951E-01,3.6458E-03,2.3544E-01  
 -544,0132,0197,1.7647E-01,3.9270E-03,6.0270E-01  
 -545,0132,0198,1.7647E-01,3.9270E-03,3.9730E-01  
 -546,0126,0197,1.7647E-01,5.1051E-03,7.8793E-01  
 -547,0126,0198,1.7647E-01,5.1051E-03,2.1207E-01  
 -548,0111,0148,1.7647E-01,1.6179E-02,1.1980E-02  
 -549,0111,0197,1.7647E-01,1.6179E-02,9.3038E-01  
 -550,0111,0198,1.7647E-01,1.6179E-02,5.7640E-02

COMM

COMM New Paths (continue gas to Vollrath inside wall)

COMM

0551,0136,0052,1.5340E-01,3.9490E-03,6.9424E-03  
 0552,0137,0052,1.5340E-01,4.1140E-03,6.9424E-03  
 0553,0142,0062,1.5340E-01,6.7268E-03,6.9424E-03

COMM

COMM Lower button conduction paths

COMM

0554,0150,0153,6.5000E+00,7.8540E-05,3.2271E-03  
 0555,0153,0157,6.5000E+00,7.8540E-05,7.1328E-03  
 0556,0157,0162,6.5000E+00,7.8540E-05,1.1369E-02  
 0557,0151,0154,6.5000E+00,6.2832E-04,2.6642E-03  
 0558,0154,0158,6.5000E+00,6.2832E-04,7.1328E-03  
 0559,0158,0163,6.5000E+00,6.2832E-04,1.1369E-02  
 0560,0155,0159,6.5000E+00,1.2566E-03,6.0714E-03  
 0561,0159,0164,6.5000E+00,1.2566E-03,1.1369E-02  
 0562,0160,0165,6.5000E+00,2.4544E-03,8.9862E-03  
 0563,0150,0151,6.5000E+00,6.3410E-05,4.4907E-03  
 0564,0153,0154,6.5000E+00,1.3548E-04,5.7565E-03  
 0565,0154,0155,6.5000E+00,4.0643E-04,7.2020E-03  
 0566,0157,0158,6.5000E+00,3.1269E-04,5.7565E-03  
 0567,0158,0159,6.5000E+00,9.3807E-04,9.1783E-03  
 0568,0159,0160,6.5000E+00,1.5635E-03,8.3451E-03  
 0569,0162,0163,6.5000E+00,4.0167E-04,5.7565E-03  
 0570,0163,0164,6.5000E+00,1.2050E-03,9.1783E-03  
 0571,0164,0165,6.5000E+00,2.0083E-03,1.0890E-02  
 0572,0165,0166,6.5000E+00,3.0125E-03,8.4994E-03  
 0573,0150,0149,6.5000E+00,7.8731E-05,1.0683E-03  
 0574,0151,0152,6.5000E+00,6.4425E-04,4.9547E-04  
 0575,0155,0156,6.5000E+00,1.3764E-03,9.9950E-04  
 0576,0160,0161,6.5000E+00,3.1769E-03,2.0036E-03  
 0577,0166,0167,6.5000E+00,4.0810E-03,1.8881E-03  
 0578,0162,0168,6.5000E+00,7.8540E-05,6.3928E-03  
 0579,0163,0169,6.5000E+00,6.2832E-04,6.3928E-03  
 0580,0164,0170,6.5000E+00,1.2566E-03,6.3928E-03  
 0581,0165,0171,6.5000E+00,2.4544E-03,6.3928E-03  
 0582,0166,0172,6.5000E+00,2.2394E-03,3.4407E-03

COMM

COMM Upper button conduction paths (assumes that buttons are identical)  
COMM

0583,0174,0177,6.5000E+00,7.8540E-05,3.2271E-03  
0584,0177,0181,6.5000E+00,7.8540E-05,7.1328E-03  
0585,0181,0186,6.5000E+00,7.8540E-05,1.1369E-02  
0586,0175,0178,6.5000E+00,6.2832E-04,2.6642E-03  
0587,0178,0182,6.5000E+00,6.2832E-04,7.1328E-03  
0588,0182,0187,6.5000E+00,6.2832E-04,1.1369E-02  
0589,0179,0183,6.5000E+00,1.2566E-03,6.0714E-03  
0590,0183,0188,6.5000E+00,1.2566E-03,1.1369E-02  
0591,0184,0189,6.5000E+00,2.4544E-03,8.9862E-03  
0592,0174,0175,6.5000E+00,6.3410E-05,4.4907E-03  
0593,0177,0178,6.5000E+00,1.3548E-04,5.7565E-03  
0594,0178,0179,6.5000E+00,4.0643E-04,7.2020E-03  
0595,0181,0182,6.5000E+00,3.1269E-04,5.7565E-03  
0596,0182,0183,6.5000E+00,9.3807E-04,9.1783E-03  
0597,0183,0184,6.5000E+00,1.5635E-03,8.3451E-03  
0598,0186,0187,6.5000E+00,4.0167E-04,5.7565E-03  
0599,0187,0188,6.5000E+00,1.2050E-03,9.1783E-03  
0600,0188,0189,6.5000E+00,2.0083E-03,1.0890E-02  
0601,0189,0190,6.5000E+00,3.0125E-03,8.4994E-03  
0602,0174,0173,6.5000E+00,7.8731E-05,1.0683E-03  
0603,0175,0176,6.5000E+00,6.4425E-04,4.9547E-04  
0604,0179,0180,6.5000E+00,1.3764E-03,9.9950E-04  
0605,0184,0185,6.5000E+00,3.1769E-03,2.0036E-03  
0606,0190,0191,6.5000E+00,4.0810E-03,1.8881E-03  
0607,0186,0192,6.5000E+00,7.8540E-05,6.3928E-03  
0608,0187,0193,6.5000E+00,6.2832E-04,6.3928E-03  
0609,0188,0194,6.5000E+00,1.2566E-03,6.3928E-03  
0610,0189,0195,6.5000E+00,2.4544E-03,6.3928E-03  
0611,0190,0196,6.5000E+00,2.2394E-03,3.4407E-03

COMM

COMM Connections from the lower button surface to Vollrath gas  
COMM

0612,0149,0036,1.5340E-01,7.8731E-05,6.1466E-05  
0613,0152,0037,1.5340E-01,6.4425E-04,6.0907E-04  
0614,0156,0038,1.5340E-01,1.3764E-03,2.0030E-03  
0615,0161,0039,1.5340E-01,3.1769E-03,4.3818E-03  
0616,0167,0136,1.5340E-01,4.0810E-03,4.1717E-03  
0617,0168,0047,1.5340E-01,7.8540E-05,6.1615E-05  
0618,0169,0048,1.5340E-01,6.2832E-04,6.2451E-04  
0619,0170,0049,1.5340E-01,1.2566E-03,2.1939E-03  
0620,0171,0050,1.5340E-01,2.4544E-03,5.6718E-03  
0621,0172,0051,1.5340E-01,2.2394E-03,8.2653E-03

COMM

COMM Connections from the upper button surface to Vollrath gas  
COMM

0622,0173,0047,1.5340E-01,7.8731E-05,6.1466E-05  
0623,0176,0048,1.5340E-01,6.4425E-04,6.0907E-04  
0624,0180,0049,1.5340E-01,1.3764E-03,2.0030E-03  
0625,0185,0050,1.5340E-01,3.1769E-03,4.3818E-03  
0626,0191,0137,1.5340E-01,4.0810E-03,4.2757E-03  
0627,0192,0138,1.5340E-01,7.8540E-05,1.0326E-02  
0628,0193,0139,1.5340E-01,6.2832E-04,1.0326E-02  
0629,0194,0140,1.5340E-01,1.2566E-03,1.0326E-02  
0630,0195,0141,1.5340E-01,2.4544E-03,1.0326E-02  
0631,0196,0142,1.5340E-01,2.2394E-03,1.8233E-02

COMM

COMM Additional radiation paths for the Vollrath interior  
 COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT  
 COMM (m<sup>2</sup>) , (-)  
 -632,0196,0072,2.3077E-01,2.2394E-03,9.6520E-02  
 -633,0196,0082,2.3077E-01,2.2394E-03,7.5440E-02  
 -634,0196,0093,2.3077E-01,2.2394E-03,1.0146E-01  
 -635,0196,0092,2.3077E-01,2.2394E-03,7.1430E-02  
 -636,0196,0091,2.3077E-01,2.2394E-03,3.8920E-02  
 -637,0196,0090,2.3077E-01,2.2394E-03,2.2530E-02  
 -638,0062,0072,1.7647E-01,1.3422E-02,9.8860E-02  
 -639,0062,0082,1.7647E-01,1.3422E-02,7.7440E-02  
 -640,0062,0093,1.7647E-01,1.3422E-02,5.7210E-02  
 -641,0062,0092,1.7647E-01,1.3422E-02,5.3340E-02  
 -642,0062,0091,1.7647E-01,1.3422E-02,3.2010E-02  
 -643,0062,0090,1.7647E-01,1.3422E-02,1.9170E-02  
 -644,0072,0082,1.7647E-01,5.3703E-03,1.3510E-01  
 -645,0072,0093,1.7647E-01,5.3703E-03,1.1126E-01  
 -646,0072,0092,1.7647E-01,5.3703E-03,1.0167E-01  
 -647,0072,0091,1.7647E-01,5.3703E-03,5.0960E-02  
 -648,0072,0090,1.7647E-01,5.3703E-03,2.7210E-02  
 -649,0082,0093,1.7647E-01,5.9979E-03,2.8310E-01  
 -650,0082,0092,1.7647E-01,5.9979E-03,9.0270E-02  
 -651,0082,0091,1.7647E-01,5.9979E-03,3.1040E-02  
 -652,0082,0090,1.7647E-01,5.9979E-03,1.4360E-02  
 COMM  
 COMM Radiation paths inside the drum (continued)  
 COMM  
 -653,0102,0148,1.7647E-01,1.6233E-02,7.0510E-02  
 -654,0102,0197,1.7647E-01,1.6233E-02,9.1893E-01  
 -655,0102,0198,1.7647E-01,1.6233E-02,1.0560E-02  
 -656,0088,0148,1.7647E-01,7.5006E-03,3.2001E-01  
 -657,0088,0197,1.7647E-01,7.5006E-03,6.7999E-01  
 -658,0076,0148,1.7647E-01,6.5047E-03,6.6038E-01  
 -659,0076,0197,1.7647E-01,6.5047E-03,3.3962E-01  
 -660,0066,0148,1.7647E-01,1.6258E-02,9.1928E-01  
 -661,0066,0197,1.7647E-01,1.6258E-02,8.0720E-02  
 -662,0056,0144,2.1951E-01,1.6258E-02,4.0660E-02  
 -663,0056,0148,1.7647E-01,1.6258E-02,9.4633E-01  
 -664,0056,0197,1.7647E-01,1.6258E-02,1.3010E-02  
 -665,0046,0144,2.1951E-01,8.2467E-03,1.8504E-01  
 -666,0046,0148,1.7647E-01,8.2467E-03,8.1496E-01  
 -667,0012,0144,2.1951E-01,3.5343E-03,4.0747E-01  
 -668,0012,0148,1.7647E-01,3.5343E-03,5.9253E-01  
 -669,0144,0148,2.1951E-01,1.2115E-02,6.2374E-01  
 -670,0144,0197,2.1951E-01,1.2115E-02,3.9230E-02  
 -671,0144,0198,2.1951E-01,1.2115E-02,1.0350E-02  
 -672,0144,0200,2.9032E-01,1.2115E-02,9.6900E-03  
 -673,0148,0197,1.7647E-01,7.1614E-02,4.5730E-02  
 -674,0148,0198,1.7647E-01,7.1614E-02,5.0300E-03  
 -675,0197,0198,1.7647E-01,6.8997E-02,7.8020E-02  
 -676,0197,0200,2.1951E-01,6.8997E-02,3.1620E-02  
 -677,0198,0200,2.1951E-01,7.8215E-02,2.4018E-01  
 -678,0198,0207,2.1951E-01,7.8920E-02,2.6220E-02  
 -679,0198,0208,2.1951E-01,7.8920E-02,1.6935E-01  
 -680,0198,0209,2.1951E-01,7.8920E-02,6.0874E-01  
 -681,0198,0202,2.1951E-01,7.8920E-02,1.9569E-01  
 -682,0197,0146,2.1951E-01,6.9619E-02,2.6500E-02  
 -683,0197,0207,2.1951E-01,6.9619E-02,1.8813E-01

-684,0197,0208,2.1951E-01,6.9619E-02,5.7073E-01  
-685,0197,0209,2.1951E-01,6.9619E-02,1.9202E-01  
-686,0197,0202,2.1951E-01,6.9619E-02,2.2620E-02  
-687,0148,0146,2.1951E-01,7.2260E-02,2.0901E-01  
-688,0148,0207,2.1951E-01,7.2260E-02,5.8209E-01  
-689,0148,0208,2.1951E-01,7.2260E-02,1.8123E-01  
-690,0148,0209,2.1951E-01,7.2260E-02,2.7660E-02  
-691,0146,0207,2.9032E-01,7.4486E-02,5.0949E-01  
-692,0146,0208,2.9032E-01,7.4486E-02,1.3507E-01  
-693,0146,0209,2.9032E-01,7.4486E-02,5.6610E-02  
-694,0146,0202,2.9032E-01,7.4486E-02,6.4700E-02  
-695,0207,0208,2.9032E-01,1.4452E-01,9.7380E-02  
-696,0207,0209,2.9032E-01,1.4452E-01,3.7450E-02  
-697,0207,0202,2.9032E-01,1.4452E-01,2.5540E-02  
-698,0208,0209,2.9032E-01,1.3924E-01,1.0611E-01  
-699,0208,0202,2.9032E-01,1.3924E-01,6.5460E-02  
-700,0209,0202,2.9032E-01,1.5784E-01,2.5046E-01  
-701,0143,0205,7.8571E-01,1.2272E-02,1.5100E-02  
-702,0144,0205,7.8571E-01,1.2557E-02,1.9870E-02  
-703,0146,0205,7.8571E-01,7.4486E-02,1.3980E-01

COMM

COMM Conduction paths in the cabinet

COMM

0704,0224,0204,1.5130E+01,4.5615E-03,5.2832E-02  
0705,0224,0225,1.5130E+01,6.0484E-05,2.5400E-02  
0706,0224,0228,1.5130E+01,6.0484E-05,2.5400E-02  
0707,0225,0226,1.5130E+01,3.7500E-03,1.3930E-01  
0708,0226,0227,1.5130E+01,3.7500E-03,1.3376E-01  
0709,0227,0228,1.5130E+01,3.7500E-03,2.4170E-01  
0710,0220,0221,1.2905E-01,7.8904E-02,1.3811E-01  
0711,0221,0222,1.2905E-01,7.8904E-02,1.3376E-01  
0712,0222,0223,1.2905E-01,7.8904E-02,2.4051E-01

COMM

COMM Convection paths from the drum outer surface and  
COMM the cabinet shelf and door to air

COMM

0713,0224,0220,1.8400E+00,7.8904E-02,1.0000E+00  
0714,0205,0220,1.4100E+00,2.4156E-02,1.0000E+00  
0715,0207,0220,1.4100E+00,1.4670E-01,1.0000E+00  
0716,0208,0221,1.4100E+00,1.4048E-01,1.0000E+00  
0717,0209,0222,1.4100E+00,1.6104E-01,1.0000E+00  
0718,0202,0223,1.8400E+00,7.6489E-02,1.0000E+00  
0719,0200,0223,1.8400E+00,2.4607E-02,1.0000E+00  
0720,0224,0218,1.8400E+00,2.4607E-02,1.0000E+00  
0721,0224,0219,1.8400E+00,7.4708E-02,1.0000E+00  
0722,0224,0223,9.2000E-01,1.8000E-01,1.0000E+00  
0723,0225,0220,1.4100E+00,6.0618E-02,1.0000E+00  
0724,0226,0221,1.4100E+00,4.9069E-02,1.0000E+00  
0725,0227,0222,1.4100E+00,5.6250E-02,1.0000E+00  
0726,0228,0223,1.4100E+00,1.3406E-01,1.0000E+00

COMM

COMM Radiation paths between the drum outer surface and  
COMM the cabinet front and back

COMM

-727,0200,0224,1.7647E-01,2.4607E-02,8.0932E-01  
-728,0200,0228,1.7647E-01,2.4607E-02,1.9068E-01  
-729,0202,0224,1.7647E-01,7.6489E-02,8.0932E-01  
-730,0202,0228,1.7647E-01,7.6489E-02,1.9068E-01

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-731,0209,0208,1.7647E-01,1.6104E-01,5.4930E-02
-732,0209,0224,1.7647E-01,1.6104E-01,1.0309E-01
-733,0209,0225,1.7647E-01,1.6104E-01,1.0890E-02
-734,0209,0226,1.7647E-01,1.6104E-01,8.5020E-02
-735,0209,0227,1.7647E-01,1.6104E-01,3.9557E-01
-736,0209,0228,1.7647E-01,1.6104E-01,5.6920E-02
-737,0208,0207,1.7647E-01,1.4048E-01,5.8900E-02
-738,0208,0224,1.7647E-01,1.4048E-01,2.1490E-02
-739,0208,0225,1.7647E-01,1.4048E-01,9.8770E-02
-740,0208,0226,1.7647E-01,1.4048E-01,3.7493E-01
-741,0208,0227,1.7647E-01,1.4048E-01,9.7590E-02
-742,0208,0228,1.7647E-01,1.4048E-01,9.3400E-03
-743,0207,0224,1.7647E-01,1.7086E-01,1.5085E-01
-744,0207,0225,1.7647E-01,1.7086E-01,4.0424E-01
-745,0207,0226,1.7647E-01,1.7086E-01,8.1070E-02
-746,0207,0227,1.7647E-01,1.7086E-01,1.2790E-02
-747,0205,0224,1.7647E-01,2.3055E-02,4.7182E-01
-748,0146,0224,1.7647E-01,7.4708E-02,8.6020E-01
-749,0144,0224,1.7647E-01,1.2336E-02,9.8013E-01
-750,0143,0224,1.7647E-01,1.2272E-02,9.8490E-01
-751,0224,0225,1.7647E-01,7.8918E-02,3.5815E-01
-752,0224,0226,1.7647E-01,7.8918E-02,5.1810E-02
-753,0224,0227,1.7647E-01,7.8918E-02,1.9990E-02
-754,0224,0228,1.7647E-01,7.8918E-02,1.5160E-02
-755,0224,0227,1.7647E-01,1.8000E-01,2.1510E-02
-756,0224,0228,1.7647E-01,1.8000E-01,4.0304E-01

COMM
COMM Convection and Radiation to boundary temperature node
COMM
    0757,0225,0229,1.4100E+01,6.0618E-02,1.0000E+00
    0758,0226,0229,1.4100E+01,4.9069E-02,1.0000E+00
    0759,0227,0229,1.4100E+01,5.6250E-02,1.0000E+00
    0760,0228,0229,1.4100E+01,1.3406E-01,1.0000E+00
    -761,0225,0229,1.7647E-01,6.0618E-02,1.0000E+00
    -762,0226,0229,1.7647E-01,4.9069E-02,1.0000E+00
    -763,0227,0229,1.7647E-01,5.6250E-02,1.0000E+00
    -764,0228,0229,1.7647E-01,1.3406E-01,1.0000E+00

ENDD
CNTL DATA
    TSTP=0.0
    BETA,0.5,
    DCNV,0.000001,
    NLOP,0,
    TEND,0.0,
    IPRT,0,
    ISTA,0,
    RLAX,1.0,
    IPRO,2,
ENDD
VAB1 DATA
    COMMON/HCOND/HKODX(66)
    DIMENSION DXH(66)
    DIMENSION AH(66),DLH(66),ICH(66),ISH(66),IGH(66),IDH(66)
    DIMENSION AA(52),DLA(52),ICA(52),ISA(52),IGA(52),IDA(52)
    DIMENSION IP(58),N1(58),N2(58),AP(58),DX(58)

C
C      DXH IS THE CONDUCTION HEAT-TRANSFER DISTANCE
C      BETWEEN SURFACE AND HELIUM NODES

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C      (DX OR DR FOR GAS/SURFACE PATHS INSIDE BNFL
C      DEFINED IN ICH)
DATA DXH/6.1615E-05,6.2451E-04,2.1939E-03,5.6718E-03,
1      7.9963E-03,9.2500E-03,9.2500E-03,9.2500E-03,
2      9.2500E-03,9.2500E-03,2.0668E-02,2.0668E-02,
3      2.0668E-02,2.0668E-02,2.0668E-02,2.0668E-02,
4      2.0600E-02,2.0600E-02,2.0600E-02,2.0600E-02,
5      2.0600E-02,2.0600E-02,5.7500E-03,5.7500E-03,
6      5.7500E-03,5.7500E-03,5.7500E-03,5.7500E-03,
7      2.4209E-03,5.7500E-03,5.7500E-03,5.7500E-03,
8      5.7500E-03,5.7500E-03,5.7500E-03,6.2610E-03,
9      6.9424E-03,6.9424E-03,6.9424E-03,6.9424E-03,
A      7.6126E-03,2.2973E-03,2.2973E-03,6.9424E-03,
B      6.9424E-03,6.9424E-03,6.1466E-05,6.0907E-04,
C      2.0030E-03,4.3818E-03,4.1717E-03,6.1615E-05,
D      6.2451E-04,2.1939E-03,5.6718E-03,8.2653E-03,
E      6.1466E-05,6.0907E-04,2.0030E-03,4.3818E-03,
F      4.2757E-03,1.0326E-02,1.0326E-02,1.0326E-02,
G      1.0326E-02,1.8233E-02/
C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      (AREA FROM THE GAS/SURFACE PATHS DEFINED IN ICH)
DATA AH/7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
1      3.2289E-03,7.8540E-05,6.2832E-04,1.2566E-03,
2      2.4544E-03,4.4069E-03,7.8540E-05,6.2832E-04,
3      1.2566E-03,2.4544E-03,4.2082E-03,3.9961E-04,
4      7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
5      4.2082E-03,1.5810E-03,7.8540E-05,6.2832E-04,
6      1.2566E-03,2.4544E-03,4.2082E-03,1.0508E-03,
7      3.6898E-03,7.8540E-05,6.2832E-04,1.2566E-03,
8      2.4544E-03,4.2082E-03,2.4960E-03,5.0293E-03,
9      5.3594E-03,6.6956E-03,5.3703E-03,5.2198E-03,
A      7.9922E-04,1.4804E-02,1.4755E-02,3.9490E-03,
B      4.1140E-03,6.7268E-03,7.8731E-05,6.4425E-04,
C      1.3764E-03,3.1769E-03,4.0810E-03,7.8540E-05,
D      6.2832E-04,1.2566E-03,2.4544E-03,2.2394E-03,
E      7.8731E-05,6.4425E-04,1.3764E-03,3.1769E-03,
F      4.0810E-03,7.8540E-05,6.2832E-04,1.2566E-03,
G      2.4544E-03,2.2394E-03/
C
C      DLH IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      (FULL HEIGHT OF VERTICAL SURFACES OR SQRT(FULL AREA) FOR
C      HORIZONTAL SURFACES; DEFINED FOR PATHS LISTED IN ICH)
DATA DLH/8.6942E-02,8.6942E-02,8.6942E-02,8.6942E-02,
1      8.6942E-02,9.1459E-02,9.1459E-02,9.1459E-02,
2      9.1459E-02,9.1459E-02,9.5004E-02,9.5004E-02,
3      9.5004E-02,9.5004E-02,9.5004E-02,9.5004E-02,
4      1.0103E-01,1.0103E-01,1.0103E-01,1.0103E-01,
5      1.0103E-01,1.0103E-01,1.0369E-01,1.0369E-01,
6      1.0369E-01,1.0369E-01,1.0369E-01,1.0369E-01,
7      1.0369E-01,1.0546E-01,1.0546E-01,1.0546E-01,
8      1.0546E-01,1.0546E-01,1.0546E-01,1.3500E-01,
9      1.3500E-01,1.3500E-01,1.3500E-01,1.3500E-01,
A      1.3500E-01,8.2536E-02,8.2536E-02,1.3500E-01,
B      1.3500E-01,1.3500E-01,8.1592E-02,8.1592E-02,
C      8.1592E-02,8.1592E-02,8.1592E-02,8.1592E-02,

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D      8.1592E-02,8.1592E-02,8.1592E-02,8.1592E-02,
E      8.1592E-02,8.1592E-02,8.1592E-02,8.1592E-02,
F      8.1592E-02,8.1592E-02,8.1592E-02,8.1592E-02,
G      8.1592E-02,8.1592E-02/

C
C   ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C   HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C   (PATHS INSIDE THE BNFL FOR WHICH TEMPERATURE DEPENDENT
C   HTC OR CONDUCTION TO WALL WILL BE EVALUATED)
DATA ICH/032,033,034,035,036,089,090,091,092,093,
1      095,096,097,098,099,100,114,115,116,117,
2      118,119,123,124,125,126,127,128,130,132,
3      133,134,135,136,137,203,204,205,206,207,
4      214,223,224,551,552,553,612,613,614,615,
5      616,617,618,619,620,621,622,623,624,625,
6      626,627,628,629,630,631/

C
C   ISH IS THE SURFACE NODE NUMBER FOR CONVECTION
C   HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C   (SURFACE NODES FROM THE PATHS IN ICH)
DATA ISH/133,134,135,034,035,089,090,091,092,093,
1      089,090,091,092,093,084,112,113,114,115,
2      116,117,112,113,114,115,116,117,118,127,
3      128,129,130,131,132,041,052,062,072,082,
4      084,100,109,052,052,062,149,152,156,161,
5      167,168,169,170,171,172,173,176,180,185,
6      191,192,193,194,195,196/

C
C   IGH IS THE HELIUM (GAS) NODE NUMBER FOR CONVECTION
C   HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C   (GAS NODES FROM THE PATHS IN ICH)
DATA IGH/036,037,038,039,040,077,078,079,080,081,
1      094,095,096,097,098,099,103,104,105,106,
2      107,108,119,120,121,122,123,124,124,119,
3      120,121,122,123,124,040,051,061,071,081,
4      081,099,108,136,137,142,036,037,038,039,
5      136,047,048,049,050,051,047,048,049,050,
6      137,138,139,140,141,142/

C
C   IDH DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C   HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C   (FOR PATHS IN ICH)
C   -1 = HORIZONTAL BOTTOM SURFACE (GAS BELOW SURFACE)
C   0 = VERTICAL SURFACE
C   1 = HORIZONTAL TOP SURFACE (GAS ABOVE SURFACE)
DATA IDH/+1,+1,+1,+1,+1,-1,-1,-1,-1,
1      +1,+1,+1,+1,+1,-1,-1,-1,-1,
2      -1,-1,+1,+1,+1,+1,+1,+1,-1,
3      -1,-1,-1,-1,-1, 0, 0, 0, 0, 0,
4      0, 0, 0, 0, 0,-1,-1,-1, 0,
5      0,+1,+1,+1,+1,+1,-1,-1,-1, 0,
6      0,+1,+1,+1,+1,+1/

C
C   AA IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C   VECTION HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA AA/3.5343E-03,8.2467E-03,1.6258E-02,1.6258E-02,
1      6.5047E-03,7.5006E-03,1.6233E-02,1.6179E-02,
2      5.1051E-03,3.9270E-03,3.6458E-03,4.2082E-03,

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3      2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
4      7.1614E-02,6.8997E-02,7.8215E-02,7.2260E-02,
5      6.9619E-02,7.8920E-02,2.3055E-02,1.4452E-01,
6      1.3924E-01,1.5784E-01,1.2272E-02,1.2557E-02,
7      7.4486E-02,1.2115E-02,7.4486E-02,1.2272E-02,
8      1.2115E-02,7.4486E-02,7.8904E-02,2.4156E-02,
9      1.4670E-01,1.4048E-01,1.6104E-01,7.6489E-02,
A      2.4607E-02,2.4607E-02,7.4708E-02,1.8000E-01,
B      5.9681E-02,4.9069E-02,5.6250E-02,1.3312E-01,
C      1.2124E-01,9.8138E-02,1.1250E-01,2.6812E-01/
C
C      DLA IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA DLA/10*2.5400E-01,6*1.2500E-01,6*3.9529E-01,
1      2.0637E-02,3*3.9529E-01,3*3.5560E-01,
2      2.5606E-02,8.8900E-02,2*1.7621E-01,
3      8.8900E-02,7.7813E-02,4*4.1910E-01,
4      2*3.1796E-01,2*3.1514E-01,4.2426E-01,
5      4*7.5724E-01,4*2.1336E+00/
C
C      ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA ICA/472,473,474,475,476,477,478,479,480,481,
1      482,483,484,485,486,487,488,489,490,491,
2      492,493,494,495,496,497,498,499,500,501,
3      502,503,504,505,713,714,715,716,717,718,
4      719,720,721,722,723,724,725,726,757,758,
5      759,760/
C
C      ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA ISA/012,046,056,066,076,088,102,111,126,132,
1      132,131,130,129,128,127,148,197,198,148,
2      197,198,205,207,208,209,143,144,146,144,
3      146,200,200,202,204,205,207,208,209,202,
4      200,224,224,224,225,226,227,228,225,226,
5      227,228/
C
C      IGA IS THE AIR NODE NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA IGA/5*211,5*212,6*214,211,212,213,215,216,
1      217,219,215,216,217,2*218,219,211,215,
2      214,213,217,3*220,221,222,2*223,218,
3      219,223,220,221,222,223,4*229/
C
C      IDA DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
C      -1 = HORIZONTAL BOTTOM SURFACE
C      0 = VERTICAL SURFACE
C      1 = HORIZONTAL TOP SURFACE
DATA IDA/10*0,6*1,10*0,3*-1,2*1,3*-1,1,4*0,4*1,-1,
1      8*0/
C
C      IP IS THE HEAT-TRANSFER PATH NUMBER FOR CONDUCTION
C      HEAT TRANSFER BETWEEN PU-METAL NODES
C      (FOR WHICH TEMPERATURE-DEPENDENT K IS CALCULATED)
DATA IP/554,555,556,557,558,559,560,561,562,563,
1      564,565,566,567,568,569,570,571,572,573,

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2      574,575,576,577,578,579,580,581,582,583,
3      584,585,586,587,588,589,590,591,592,593,
4      594,595,596,597,598,599,600,601,602,603,
5      604,605,606,607,608,609,610,611/
C
C   N1 IS THE FIRST PU-METAL NODE NUMBER
C       (FOR PATHS IN IP)
DATA N1/150,153,157,151,154,158,155,159,160,150,
1      153,154,157,158,159,162,163,164,165,150,
2      151,155,160,166,162,163,164,165,166,174,
3      177,181,175,178,182,179,183,184,174,177,
4      178,181,182,183,186,187,188,189,174,175,
5      179,184,190,186,187,188,189,190/
C
C   N2 IS THE SECOND PU-METAL NODE NUMBER
C       (FOR PATHS IN IP)
DATA N2/153,157,162,154,158,163,159,164,165,151,
1      154,155,158,159,160,163,164,165,166,149,
2      152,156,161,167,168,169,170,171,172,177,
3      181,186,178,182,187,183,188,189,175,178,
4      179,182,183,184,187,188,189,190,173,176,
5      180,185,191,192,193,194,195,196/
C
C   AP IS THE CONDUCTION HEAT-TRANSFER AREA
C       BETWEEN PU-METAL VOLUME AND SURFACE NODES
C       (FOR PATHS IN IP)
DATA AP/7.8540E-05,7.8540E-05,7.8540E-05,6.2832E-04,
1      6.2832E-04,6.2832E-04,1.2566E-03,1.2566E-03,
2      2.4544E-03,6.3410E-05,1.3548E-04,4.0643E-04,
3      3.1269E-04,9.3807E-04,1.5635E-03,4.0167E-04,
4      1.2050E-03,2.0083E-03,3.0125E-03,7.8731E-05,
5      6.4425E-04,1.3764E-03,3.1769E-03,4.0810E-03,
6      7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
7      2.2394E-03,7.8540E-05,7.8540E-05,7.8540E-05,
8      6.2832E-04,6.2832E-04,6.2832E-04,1.2566E-03,
9      1.2566E-03,2.4544E-03,6.3410E-05,1.3548E-04,
A      4.0643E-04,3.1269E-04,9.3807E-04,1.5635E-03,
B      4.0167E-04,1.2050E-03,2.0083E-03,3.0125E-03,
C      7.8731E-05,6.4425E-04,1.3764E-03,3.1769E-03,
D      4.0810E-03,7.8540E-05,6.2832E-04,1.2566E-03,
E      2.4544E-03,2.2394E-03/
C
C   DX IS CONDUCTION HEAT-TRANSFER DISTANCE
C       BETWEEN PU-METHAL NODES
C       (FOR PATHS IN IP)
DATA DX/3.2271E-03,7.1328E-03,1.1369E-02,2.6642E-03,
1      7.1328E-03,1.1369E-02,6.0714E-03,1.1369E-02,
2      8.9862E-03,4.4907E-03,5.7565E-03,7.2020E-03,
3      5.7565E-03,9.1783E-03,8.3451E-03,5.7565E-03,
4      9.1783E-03,1.0890E-02,8.4994E-03,1.0683E-03,
5      4.9547E-04,9.9950E-04,2.0036E-03,1.8881E-03,
6      6.3928E-03,6.3928E-03,6.3928E-03,6.3928E-03,
7      3.4407E-03,3.2271E-03,7.1328E-03,1.1369E-02,
8      2.6642E-03,7.1328E-03,1.1369E-02,6.0714E-03,
9      1.1369E-02,8.9862E-03,4.4907E-03,5.7565E-03,
A      7.2020E-03,5.7565E-03,9.1783E-03,8.3451E-03,
B      5.7565E-03,9.1783E-03,1.0890E-02,8.4994E-03,
C      1.0683E-03,4.9547E-04,9.9950E-04,2.0036E-03,

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D      1.8881E-03,6.3928E-03,6.3928E-03,6.3928E-03,
E      6.3928E-03,3.4407E-03/
C
C      HELIUM THERMAL CONDUCTIVITY = HTK0*(0.5*(TL+TR)+HTK1)**HTK2
C      HELIUM SPECIFIC HEAT = HSH0
C      HELIUM VISCOSITY = HVIO+AHVI1*(TL+TR)+AQVI2*(TL+TR)**2
C      HELIUM DENSITY = HDNO/(HDN1+273.16)
C
C      DATA HTK0/3.3366E-03/,HTK1/2.7316E+02/,HTK2/6.6800E-01/
C      DATA HVIO/6.8531E-02/,HHVI1/7.85947E-05/,HQVI2/-1.38105E-08/
C      DATA HDNO/4.8792E+01/,HDN1/2.7316E+02/,HSH0/1.4539E+00/
C
C      AIR THERMAL CONDUCTIVITY = ATK0+AHTK1*(TL+TR)+AQTK2*(TL+TR)**2
C      AIR SPECIFIC HEAT = ASH0+AHSH1*(TL+TR)+AQSH2*(TL+TR)**2
C      AIR VISCOSITY = AVIO+AHVI1*(TL+TR)+AQVI2*(TL+TR)**2
C      AIR DENSITY = ADNO/(ADN1+T) WHERE T,TL,&TR ARE TEMPERATURES
C
C      DATA ATK0/2.3991E-02/,AHTK1/3.30685E-05/,AQTK2/-3.49125E-09/
C      DATA ASH0/2.7625E-01/,AHSH1/2.72465E-05/,AQSH2/-1.36857E-09/
C      DATA AVIO/6.1474E-02/,AHVI1/1.06686E-04/,AQVI2/-7.3260E-08/
C      DATA ADNO/3.5308E+02/,ADN1/2.7316E+02/
C
C      EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C      A HORIZONTAL OR VERTICAL SURFACE TO A HELIUM VOLUME
C
DO 100 I=1,66
TA=T(I$H(I))+T(I$H(I))
TK=HTK0*(HTK1+0.5*TA)**HTK2
SH=HSH0
VI=HVIO+TA*(HHVI1+TA*HQVI2)
DG=HDNO/(HDN1+0.5*TA)
DT=DMAX1(0.1,DABS(T(I$H(I))-T(I$H(I))))
D3=DLH(I)*DLH(I)*DLH(I)
GR=D3*1.27094E+08*DG*DG*DT/((HDN1+T(I$H(I)))*VI*VI)
PR=SH*VI/TK
GRPR=GR*PR
IF (IDH(I).NE.0) THEN
C
C      HORIZONTAL SURFACE TO HELIUM NUSSELT NUMBER
C
1 IF (((IDH(I).EQ.-1).AND.(T(I$H(I)).GE.T(I$H(I))))).OR.
   ((IDH(I).EQ. 1).AND.(T(I$H(I)).LE.T(I$H(I))))) THEN
C
C      HOTTER SURFACE FACING UPWARD OR
C      COLDER SURFACE FACING DOWNWARD
C
1 IF (GRPR.LT.1.0844E+07) THEN
   F=DMIN1(5.0,0.43429*DLOG(GRPR))
   CNU=((F-2.0)*0.54*(GRPR**0.25)
   + (5.0-F)*0.96*(GRPR**0.20))*0.333333
ELSE
   CNU=0.14*(GRPR**0.333333)
ENDIF
ELSE
C
C      COLDER SURFACE FACING UPWARD OR
C      HOTTER SURFACE FACING DOWNWARD
C

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        F=DMIN1(5.5,0.43429*DLOG(GRPR))
        CNU=((F-2.5)*0.27*(GRPR**0.25)
1      +(5.5-F)*0.48*(GRPR**0.20))*0.33333
        ENDIF
        ELSE
C
C          VERTICAL SURFACE TO HELIUM NUSSELT NUMBER
C
        IF (GRPR.LT.7.6372E+07) THEN
            F=DMIN1(5.0,0.43429*DLOG(GRPR))
            CNU=((F-2.0)*0.59*(GRPR**0.25)
1      +(5.0-F)*1.05*(GRPR**0.20))*0.33333
        ELSE
            CNU=0.13*(GRPR**0.33333)
        ENDIF
        ENDIF
        HKODX(I)=TK/DXH(I)
        G(ICH(I))=AH(I)*DMAX1(HKODX(I),CNU*TK/DLH(I))
100    CONTINUE
C
C          EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C          A HORIZONTAL OR VERTICAL SURFACE TO AN AIR VOLUME
C
        DO 110 I=1,52
        TA=T(ISA(I))+T(IGA(I))
        TK=ATK0+TA*(AHTK1+TA*AQTK2)
        SH=ASH0+TA*(AHSH1+TA*AQSH2)
        VI=AVI0+TA*(AHVI1+TA*AQVI2)
        DG=ADN0/(ADN1+0.5*TA)
        DT=DMAX1(0.1,DABS(T(ISA(I))-T(IGA(I))))
        D3=DLA(I)*DLA(I)*DLA(I)
        GR=D3*1.27094E+08*DG*DG*DT/((ADN1+T(IGA(I)))*VI*VI)
        PR=SH*VI/TK
        GRPR=GR*PR
        IF(IDA(I).NE.0) THEN
C
C          HORIZONTAL SURFACE TO AIR NUSSELT NUMBER
C
        IF (((IDA(I).EQ.-1).AND.(T(IGA(I)).GE.T(ISA(I))))).OR.
1      ((IDA(I).EQ. 1).AND.(T(IGA(I)).LE.T(ISA(I))))) THEN
C
C          HOTTER SURFACE FACING UPWARD OR
C          COLDER SURFACE FACING DOWNWARD
C
        IF (GRPR.LT.1.0844E+07) THEN
            F=DMIN1(5.0,0.43429*DLOG(GRPR))
            CNU=((F-2.0)*0.54*(GRPR**0.25)
1      +(5.0-F)*0.96*(GRPR**0.20))*0.33333
        ELSE
            CNU=0.14*(GRPR**0.33333)
        ENDIF
        ELSE
C
C          COLDER SURFACE FACING UPWARD OR
C          HOTTER SURFACE FACING DOWNWARD
C
        F=DMIN1(5.5,0.43429*DLOG(GRPR))
        CNU=((F-2.5)*0.27*(GRPR**0.25))

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1           +(5.5-F)*0.48*(GRPR**0.20))*0.33333
      ENDIF
      ELSE
C
C      VERTICAL SURFACE TO AIR NUSSELT NUMBER
C
C      IF (GRPR.LT.7.6372E+07) THEN
C          F=DMIN1(5.0,0.43429*DLOG(GRPR))
C          CNU=((F-2.0)*0.59*(GRPR**0.25)
1          +(5.0-F)*1.05*(GRPR**0.20))*0.33333
      ELSE
C          CNU=0.13*(GRPR**0.33333)
      ENDIF
      ENDIF
      G(ICA(I))=AA(I)*CNU*TK/DLA(I)
110 CONTINUE
C
C      EVALUATE THE TEMPERATURE-DEPENDENT THERMAL
C      CONDUCTIVITY OF THE PLUTONIUM-METAL INGOT
C
C      DO 120 I=1,58
C          TA=0.5*(T(N1(I))+T(N2(I)))
C          TK=6.15856+TA*(2.11264E-02+TA*2.0E-05)
C          G(IP(I))=AP(I)*TK/DX(I)
120 CONTINUE
ENDD
VAB2 DATA
ENDD
VAB3 DATA
COMMON/HCOND/HKODX(66)
DIMENSION AH(66),H(66),ICH(66),ISH(66)
DIMENSION AA(52),ICA(52),ISA(52),IGA(52),IS1(46),IS2(46)
DIMENSION ACN(21),ADM(10),ACT(4),ICN(21),IDM(10),ICT(4)
DIMENSION IBP(20),IB1(20),IB2(20),BA(20)
DIMENSION IRLBP(35),IRLBB(35),IRLBS(35)
DIMENSION IRUBP(51),IRUBB(51),IRUBS(51)
C
C      IBP IS CONVECTION PATH NUMBERS ATTACHED TO SURFACES
C          ON THE PU BUTTONS
DATA IBP/612,613,614,615,616,617,618,619,620,621,
1           622,623,624,625,626,627,628,629,630,631/
C
C      IB1 IS THE NODE NUMBER FOR PU BUTTON SURFACES
C          (CORRESPONDING TO IBP)
DATA IB1/149,152,156,161,167,168,169,170,171,172,
1           173,176,180,185,191,192,193,194,195,196/
C
C      IB2 IS THE NODE NUMBER FOR THE GAS NODE OPPOSITE IB1
C          (ADJACENT TO PU BUTTON SURFACES)
DATA IB2/036,037,038,039,136,047,048,049,050,051,
1           047,048,049,050,137,138,139,140,141,142/
C
C      BA IS THE AREA ASSOCIATED WITH THE CONVECTION PATHS LISTED
C          IN IBP (PU BUTTON SURFACE AREAS)
DATA BA/7.8731E-05,6.4425E-04,1.3764E-03,3.1769E-03,
1           4.0810E-03,7.8540E-05,6.2832E-04,1.2566E-03,
2           2.4544E-03,2.2394E-03,7.8731E-05,6.4425E-04,
3           1.3764E-03,3.1769E-03,4.0810E-03,7.8540E-05,

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4       6.2832E-04,1.2566E-03,2.4544E-03,2.2394E-03/
C
C   IRLBP IS THE RADIATION PATH ASSOCIATED WITH LOWER PU BUTTON
C   SURFACE (BUTTON 1)
DATA IRLBP/263,264,265,267,268,269,272,273,274,277,
1           278,279,283,284,285,289,290,291,292,293,
2           294,295,296,297,298,299,300,301,302,303,
3           304,305,306,307,308/
C
C   IRLBB IS THE LOWER PU BUTTON SURFACE NODE ASSOCIATED WITH THE
C   RADIATION PATHS IN IRLBP (BUTTON 1)
DATA IRLBB/149,152,156,152,156,161,156,161,167,156,
1           161,167,156,161,167,161,167,168,169,169,
2           169,170,170,170,171,171,171,171,171,171,
3           172,172,172,172,172/
C
C   IRLBS IS THE SINK NODE (NOT THE PU BUTTON NODE) ASSOCIATED
C   WITH THE RADIATION PATHS IN IRLBP
DATA IRLBS/133,134,134,135,135,135,034,034,034,035,
1           035,035,041,041,041,041,052,052,173,176,180,
2           052,176,180,185,052,180,185,191,052,062,
3           180,185,191,052,062/
C
C   IRUBP IS THE RADIATION PATH ASSOCIATED WITH UPPER PU BUTTON
C   SURFACE (BUTTON 2)
DATA IRUBP/288,291,292,293,295,296,297,299,300,301,
1           304,305,306,309,310,311,313,314,315,316,
2           317,318,319,320,321,322,323,324,325,326,
3           327,328,329,330,331,332,333,334,335,336,
4           337,338,339,340,341,632,633,634,635,636,
5           637/
C
C   IRUBB IS THE UPPER PU BUTTON SURFACE NODE ASSOCIATED WITH THE
C   RADIATION PATHS IN IRUBP (BUTTON 2)
DATA IRUBB/191,173,176,180,176,180,185,180,185,191,
1           180,185,191,180,185,191,192,192,192,192,
2           192,192,192,193,193,193,193,193,193,193,
3           194,194,194,194,194,194,194,195,195,195,
4           195,195,195,195,196,196,196,196,196,196,
5           196/
C
C   IRUBS IS THE SINK NODE (NOT THE PU BUTTON NODE) ASSOCIATED
C   WITH THE RADIATION PATHS IN IRUBP
DATA IRUBS/041,168,169,169,170,170,170,171,171,171,
1           172,172,172,052,052,052,062,072,082,093,
2           092,091,090,062,072,082,093,092,091,090,
3           062,072,082,093,092,091,090,062,072,082,
4           093,092,091,090,062,072,082,093,092,091,
5           090/
C
C   ACN IS THE HEAT-TRANSFER AREA OF THE BNFL CONTAINER
C   SURFACE NODES
DATA ACN/7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
1           4.2082E-03,3.6458E-03,3.5343E-03,8.2467E-03,
2           1.6258E-02,1.6258E-02,6.5047E-03,7.5006E-03,
3           1.6233E-02,1.6179E-02,5.1051E-03,7.5728E-03,
4           4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
5           7.8540E-05/

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C
C      ICN IS THE BNFL CONTAINER SURFACE NODE NUMBERS
C      DATA ICN/001,002,003,004,005,006,012,046,056,066,076,
C          1           088,102,111,126,132,131,130,129,128,127/
C
C      ADM IS THE HEAT-TRANSFER AREA OF THE DRUM OUTER-
C      SURFACE NODES
C      DATA ADM/1.2272E-02,1.2557E-02,7.4486E-02,4.7211E-02,
C          1           1.7814E-03,1.4670E-01,1.4048E-01,1.6104E-01,
C          2           7.6267E-02,2.4829E-02/
C
C      IDM IS THE DRUM OUTER-SURFACE NODE NUMBER
C      DATA IDM/143,144,146,205,204,207,208,209,202,200/
C
C      ACT IS THE HEAT-TRANSFER AREA OF THE CABINET SURFACE NODES
C      DATA ACT/1.2124E-01,9.8138E-02,1.1250E-01,2.6812E-01/
C
C      ICT IS THE CABINET SURFACE NODE NUMBER
C      DATA ICT/225,226,227,228/
C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR CON-
C      VECTION HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      (INSIDE BNFL CONTAINER FOR PATHS LISTED IN ICH)
C      DATA AH/7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
C          1           3.2289E-03,7.8540E-05,6.2832E-04,1.2566E-03,
C          2           2.4544E-03,4.4069E-03,7.8540E-05,6.2832E-04,
C          3           1.2566E-03,2.4544E-03,4.2082E-03,3.9961E-04,
C          4           7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
C          5           4.2082E-03,1.5810E-03,7.8540E-05,6.2832E-04,
C          6           1.2566E-03,2.4544E-03,4.2082E-03,1.0508E-03,
C          7           3.6898E-03,7.8540E-05,6.2832E-04,1.2566E-03,
C          8           2.4544E-03,4.2082E-03,2.4960E-03,5.0293E-03,
C          9           5.3594E-03,6.6956E-03,5.3703E-03,5.2198E-03,
C          A           7.9922E-04,1.4804E-02,1.4755E-02,3.9490E-03,
C          B           4.1140E-03,6.7268E-03,7.8731E-05,6.4425E-04,
C          C           1.3764E-03,3.1769E-03,4.0810E-03,7.8540E-05,
C          D           6.2832E-04,1.2566E-03,2.4544E-03,2.2394E-03,
C          E           7.8731E-05,6.4425E-04,1.3764E-03,3.1769E-03,
C          F           4.0810E-03,7.8540E-05,6.2832E-04,1.2566E-03,
C          G           2.4544E-03,2.2394E-03/
C
C      ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      (INSIDE BNFL CONTAINER AND FOR WHICH A TEMPERATURE
C      DEPENDENT K OR HTC IS TO BE CALCULATED)
C      DATA ICH/032,033,034,035,036,089,090,091,092,093,
C          1           095,096,097,098,099,100,114,115,116,117,
C          2           118,119,123,124,125,126,127,128,130,132,
C          3           133,134,135,136,137,203,204,205,206,207,
C          4           214,223,224,551,552,553,612,613,614,615,
C          5           616,617,618,619,620,621,622,623,624,625,
C          6           626,627,628,629,630,631/
C
C      ISH IS THE SURFACE NODE NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN SURFACE AND HELIUM NODES
C      (INSIDE BNFL CONTAINER FOR PATHS LISTED IN ICH)
C      DATA ISH/133,134,135,034,035,089,090,091,092,093,
C          1           089,090,091,092,093,084,112,113,114,115,

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2      116,117,112,113,114,115,116,117,118,127,
3      128,129,130,131,132,041,052,062,072,082,
4      084,100,109,052,052,062,149,152,156,161,
5      167,168,169,170,171,172,173,176,180,185,
6      191,192,193,194,195,196/
C
DATA AA/3.5343E-03,8.2467E-03,1.6258E-02,1.6258E-02,
1      6.5047E-03,7.5006E-03,1.6233E-02,1.6179E-02,
2      5.1051E-03,3.9270E-03,3.6458E-03,4.2082E-03,
3      2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
4      7.1614E-02,6.8997E-02,7.8215E-02,7.2260E-02,
5      6.9619E-02,7.8920E-02,2.3055E-02,1.4452E-01,
6      1.3924E-01,1.5784E-01,1.2272E-02,1.2557E-02,
7      7.4486E-02,1.2115E-02,7.4486E-02,1.2272E-02,
8      1.2115E-02,7.4486E-02,7.8904E-02,2.4156E-02,
9      1.4670E-01,1.4048E-01,1.6104E-01,7.6489E-02,
A      2.4607E-02,2.4607E-02,7.4708E-02,1.8000E-01,
B      5.9681E-02,4.9069E-02,5.6250E-02,1.3312E-01,
C      1.2124E-01,9.8138E-02,1.1250E-01,2.6812E-01/
C
C   ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C       HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA ICA/472,473,474,475,476,477,478,479,480,481,
1      482,483,484,485,486,487,488,489,490,491,
2      492,493,494,495,496,497,498,499,500,501,
3      502,503,504,505,713,714,715,716,717,718,
4      719,720,721,722,723,724,725,726,757,758,
5      759,760/
C
C   ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C       HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA ISA/012,046,056,066,076,088,102,111,126,132,
1      132,131,130,129,128,127,148,197,198,148,
2      197,198,205,207,208,209,143,144,146,144,
3      146,200,200,202,204,205,207,208,209,202,
4      200,224,224,224,225,226,227,228,225,226,
5      227,228/
C
C   IGA IS THE AIR NODE NUMBER FOR CONVECTION
C       HEAT TRANSFER BETWEEN SURFACE AND AIR NODES
DATA IGA/5*211,5*212,6*214,211,212,213,215,216,
1      217,219,215,216,217,2*218,219,211,215,
2      214,213,217,3*220,221,222,2*223,218,
3      219,223,220,221,222,223,4*229/
C
C   IS1 IS THE CONTAINER SURFACE NODE NUMBER FOR RADIATION
C       HEAT TRANSFER BETWEEN CONTAINER OUTER- AND DRUM
C           INNER-SURFACE NODES
DATA IS1/2*127,2*128,2*129,2*130,2*131,4*132,2*126,
1      3*111,3*102,2*088,2*076,2*066,3*056,2*046,
2      2*012,143,144,146,205,204,205,207,208,
3      209,202,200/
C
C   IS2 IS THE DRUM SURFACE NODE NUMBER FOR RADIATION HEAT
C       TRANSFER BETWEEN CONTAINER OUTER- AND DRUM INNER-
C           SURFACE NODES
DATA IS2/198,200,198,200,198,200,198,200,198,200,
1      198,200,197,198,197,198,148,197,198,148,

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2           197,198,148,197,148,197,148,144,148,
3           197,144,148,144,148,5*220,6*221/
C
C      BACK CALCULATE HTC USED AT SELECTED GAS/SURFACE PATHS INSIDE
C          BNFL CONTAINER
DO 100 I=1,66
H(I)=G(ICH(I))/AH(I)
100 CONTINUE
WRITE(6,110)
110 FORMAT('/[H.T.PATH] HEAT-TRANSFER COEFFICIENT (W/M**2/C) ')
I2=0
DO 130 J=1,14
I1=I2+1
I2=MIN0(I2+5,66)
WRITE(6,120) (ICH(I),H(I),I=I1,I2)
WRITE(6,120) (ICH(I),HKODX(I),I=I1,I2)
120 FORMAT(' [',I3,']=',F10.4,' [',I3,']=',F10.4,' [',I3,']=',
1           F10.4,' [',I3,']=',F10.4,' [',I3,']=',F10.4)
130 CONTINUE
C
C      CALCULATE CONDUCTION, CONVECTION, AND RADIATION FROM
C          LOWER PU BUTTON (BOTTOM OF BUTTON IS DEFINED AS RING 1
C          ON THE SPHERICAL LOWER SURFACE OF BUTTON)
C          QCDBA = CONDUCTION OUT BOTTOM OF LOWER BUTTON
C          QCDSA = CONDUCTION OUT SIDE OF LOWER BUTTON
C          QCDTA = CONDUCTION OUT TOP OF LOWER BUTTON
QCDBA=0.0
QCDSA=0.0
QCDTA=0.0
C          QCVBA = CONVECTION OUT BOTTOM OF LOWER BUTTON
C          QCVSA = CONVECTION OUT SIDE (CURVED SURFACE)
C                      OF LOWER BUTTON
C          QCVTA = CONVECTION OUT TOP OF LOWER BUTTON
QCVBA=0.0
QCVSA=0.0
QCVTA=0.0
I=1
QCVBA=QCVBA+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
DO 140 I=2,5
QCVSA=QCVSA+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
140 CONTINUE
DO 145 I=6,10
QCVTA=QCVTA+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
145 CONTINUE
C          QRDBA = RADIATION OUT BOTTOM OF LOWER BUTTON
C          QRDSA = RADIATION OUT SIDE (CURVED SURFACE)
C                      OF LOWER BUTTON
C          QRDTA = RADIATION OUT TOP OF LOWER BUTTON
QRDBA=0.0
QRDSA=0.0
QRDTA=0.0
I=1
QRDBA=QRDBA+G(IRLBP(I))*((T(IRLBB(I))+273.16)**4
1                           -(T(IRLBS(I))+273.16)**4)
DO 150 I=2,17
QRDSA=QRDSA+G(IRLBP(I))*((T(IRLBB(I))+273.16)**4
1                           -(T(IRLBS(I))+273.16)**4)
150 CONTINUE

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DO 155 I=18,35
    QRDTA=QRDTA+G(IRLBP(I))*((T(IRLBB(I))+273.16)**4
1                                -(T(IRLBS(I))+273.16)**4)
155 CONTINUE
    QCDA=QCDBA+QCDSA+QCDTA
    QCVA=QCVBA+QCVSA+QCVTA
    QRDA=QRDBA+QRDSA+QRDTA
    TOTA=QCDA+QCVA+QRDA
    FCDA=QCDA/TOTA
    FCDBA=QCDBA/TOTA
    FCDSA=QCDSA/TOTA
    FCDTA=QCDTA/TOTA
    FCVA=QCVA/TOTA
    FCVBA=QCVBA/TOTA
    FCVSA=QCVSA/TOTA
    FCVTA=QCVTA/TOTA
    FRDA=QRDA/TOTA
    FRDBA=QRDBA/TOTA
    FRDSA=QRDSA/TOTA
    FRDTA=QRDTA/TOTA
    WRITE(6,190) QCDA,QCDBA,QCDSA,QCDTA,
1                QCVA,QCVBA,QCVSA,QCVTA,
2                QRDA,QRDBA,QRDSA,QRDTA,
3                TOTA,
4                FCDA,FCDBA,FCDSA,FCDTA,
5                FCVA,FCVBA,FCVSA,FCVTA,
6                FRDA,FRDBA,FRDSA,FRDTA
190 FORMAT(//
1        ' HEAT TRANSFER FROM THE LOWER PU-METAL BUTTON SURFACE'
2        '/ QCDA =',F10.6,' W, QCDBA =',F10.6,' W, QCDSA =',
3        F10.6,' W, QCDTA =',F10.6,' W'/' QCVA =',F10.6,
4        ' W, QCVBA =',F10.6,' W, QCVSA =',F10.6,' W, QCVTA =',
5        F10.6,' W'/' QRDA =',F10.6,' W, QRDBA =',F10.6,
6        ' W, QRDSA =',F10.6,' W, QRDTA =',F10.6,
7        ' W'/' TOTA =',F10.6,' W'/' FCDA =',F10.6,
8        ' , FCDBA =',F10.6,' , FCDSA =',F10.6,' , FCDTA =',
9        F10.6/' FCVA =',F10.6,' , FCVBA =',F10.6,
A        ' , FCVSA =',F10.6,' , FCVTA =',F10.6/' FRDA =',
B        F10.6,' , FRDBA =',F10.6,' , FRDSA =',F10.6,
C        ' , FRDTA =',F10.6)
C
C      CALCULATE CONDUCTION, CONVECTION, AND RADIATION FROM
C      UPPER PU BUTTON (BOTTOM OF BUTTON IS DEFINED AS RING 1
C      ON THE SPHERICAL LOWER SURFACE OF BUTTON)
C      QCDBB = CONDUCTION OUT BOTTOM OF UPPER BUTTON
C      QCDSB = CONDUCTION OUT SIDE OF UPPER BUTTON
C      QCDTB = CONDUCTION OUT TOP OF UPPER BUTTON
QCDBB=0.0
QCDSB=0.0
QCDTB=0.0
C      QCVBB = CONVECTION OUT BOTTOM OF UPPER BUTTON
C      QCVSB = CONVECTION OUT SIDE (CURVED SURFACE)
C                  OF UPPER BUTTON
C      QCVTB = CONVECTION OUT TOP OF UPPER BUTTON
QCVBB=0.0
QCVSB=0.0
QCVTB=0.0
I=11

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        QCVBB=QCVBB+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
        DO 160 I=12,15
        QCVSB=QCVSB+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
160    CONTINUE
        DO 165 I=16,20
        QCVTB=QCVTB+G(IBP(I))*(T(IB1(I))-T(IB2(I)))
165    CONTINUE
C           QRDBB = RADIATION OUT BOTTOM OF UPPER BUTTON
C           QRDSB = RADIATION OUT SIDE (CURVED SURFACE)
C                           OF UPPER BUTTON
C           QRDTB = RADIATION OUT TOP OF UPPER BUTTON
QRDBB=0.0
QRDSB=0.0
QRDTB=0.0
I=2
QRDBB=QRDBB+G(IRUBP(I))*((T(IRUBB(I))+273.16)**4
1                         -(T(IRUBS(I))+273.16)**4)
DO 170 I=1,16
IF(I.NE.2) THEN
    QRDSB=QRDSB+G(IRUBP(I))*((T(IRUBB(I))+273.16)**4
1                         -(T(IRUBS(I))+273.16)**4)
ENDIF
170    CONTINUE
DO 175 I=17,51
    QRDTB=QRDTB+G(IRUBP(I))*((T(IRUBB(I))+273.16)**4
1                         -(T(IRUBS(I))+273.16)**4)
175    CONTINUE
QCDB=QCDBB+QCDSB+QCDTB
QCVB=QCVBB+QCVSB+QCVTB
QRDB=QRDBB+QRDSB+QRDTB
TOTB=QCDB+QCVB+QRDB
FCDB=QCDB/TOTB
FCDBB=QCDBB/TOTB
FCDSB=QCDSB/TOTB
FCDTB=QCDTB/TOTB
FCVB=QCVB/TOTB
FCVBB=QCVBB/TOTB
FCVSB=QCVSB/TOTB
FCVTB=QCVTB/TOTB
FRDB=QRDB/TOTB
FRDBB=QRDBB/TOTB
FRDSB=QRDSB/TOTB
FRDTB=QRDTB/TOTB
WRITE(6,191) QCDB,QCDBB,QCDSB,QCDTB,
1             QCVB,QCVBB,QCVSB,QCVTB,
2             QRDB,QRDBB,QRDSB,QRDTB,
3             TOTB,
4             FCDB,FCDBB,FCDSB,FCDTB,
5             FCVB,FCVBB,FCVSB,FCVTB,
6             FRDB,FRDBB,FRDSB,FRDTB
191 FORMAT(//
1           ' HEAT TRANSFER FROM THE UPPER PU-METAL BUTTON SURFACE'
2           '/ QCDB =',F10.6,' W, QCDBB =',F10.6,' W, QCDSB =',
3           F10.6,' W, QCDTB =',F10.6,' W'/' QCVB =',F10.6,
4           ' W, QCVBB =',F10.6,' W, QCVSB =',F10.6,' W, QCVTB =',
5           F10.6,' W'/' QRDB =',F10.6,' W, QRDBB =',F10.6,
6           ' W, QRDSB =',F10.6,' W, QRDTB =',F10.6,
7           ' W'/' TOTB =',F10.6,' W'/' FCDB =',F10.6,

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8      ' , FCDBB =',F10.6,' , FCDSB =',F10.6,' , FCDTB =',
9      F10.6/' FCVB =',F10.6,' , FCVBB =',F10.6,
A      ' , FCVSB =',F10.6,' , FCVTB =',F10.6/' FRDB =',
B      F10.6,' , FRDBB =',F10.6,' , FRDSB =',F10.6,
C      ' , FRDTB =',F10.6)
C
C COMPUTE OVERALL SUMMARY HEAT TRANSFER FROM BOTH PU BUTTONS
C
QCD=QCDA+QCDB
QCV=QCVA+QCVB
QRD=QRDA+QRDB
TOT=QCD+QCV+QRD
FCD=QCD/TOT
QCDB=QCDBA+QCDBB
QCDS=QCDSA+QCDSB
QCDT=QCDTA+QCDTB
QCVB=QCVBA+QCVBB
QCVS=QCVSA+QCVSB
QCVT=QCVTA+QCVTB
QRDB=QRDBA+QRDBB
QRDS=QRDSA+QRDSB
QRDT=QRDTA+QRDTB
FCDB=QCDB/TOT
FCDS=QCDS/TOT
FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,192) QCD,QCDB,QCDS,QCDT,
1          QCV,QCVB,QCVS,QCVT,
2          QRD,QRDB,QRDS,QRDT,
3          TOT,
4          FCD,FCDB,FCDS,FCDT,
5          FCV,FCVB,FCVS,FCVT,
6          FRD,FRDB,FRDS,FRDT
192 FORMAT(//' HEAT TRANSFER FROM BOTH PU-METAL INGOT SURFACES'/
1      ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2      ' W, QCDT =',F10.6,' W/' QCV =',F10.6,' W, QCVB =',
3      F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W/
4      ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5      ' W, QRDT =',F10.6,' W/' TOT =',F10.6,' W'//
6      ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7      ' , FCDT =',F10.6/' FCV =',F10.6,' , FCVB =',F10.6,
8      ' , FCVS =',F10.6,' , FCVT =',F10.6/' FRD =',F10.6,
9      ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A      F10.6)
C
C FIND MAXIMUM AND MINIMUM BUTTON TEMPERATURES AND
C MAXIMUM SURFACE TEMPERATURE AND CALCULATE
C AREA-AVERAGED SURFACE TEMPERATURE FOR EACH PU BUTTON
C
C FOR LOWER PU BUTTON
TMXA=-1.0E+10

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TMNA=1.0E+10
TSMXA=-1.0E+10
TAVA=0.0
IMXA=0
IMNA=0
ISMXA=0
ARWA=0.0
DO 200 I=149,172
IF (TMXA.LT.T(I)) THEN
    IMXA=I
    TMXA=T(I)
ENDIF
IF (TMNA.GT.T(I)) THEN
    IMNA=I
    TMNA=T(I)
ENDIF
200 CONTINUE
DO 202 I=1,10
IF (TSMXA.LT.T(IB1(I))) THEN
    ISMXA=IB1(I)
    TSMXA=T(ISMXA)
ENDIF
ARWA=ARWA+BA(I)
TAVA=TAVA+BA(I)*T(IB1(I))
202 CONTINUE
TAVA=TAVA/ARWA
TAVAF=TAVA*1.8+32.0
TSMXAF=TSMXA*1.8+32.0
TMXAF=TMXA*1.8+32.0
TMNAF=TMNA*1.8+32.0
WRITE(6,204) TMXA,TMXAF,IMXA,TMNA,TMNAF,IMNA,
1           TSMXA,TSMXAF,ISMXA,TAVA,TAVAF
204 FORMAT(//' LOWER PU BUTTON: '
1           '      MAX BUTTON T =',
2           '      C =',F9.4,' F AT NODE',I4/
3           '      MIN BUTTON T =',
4           '      C =',F9.4,' F AT NODE',I4/
5           '      MAX SURFACE T =',
6           '      C =',F9.4,' F AT NODE',I4/
7           '      AVE SURFACE T =',F9.4,' C =',F9.4,' F ')
C
C FOR UPPER PU BUTTON
TMXB=-1.0E+10
TMNB=1.0E+10
TSMXB=-1.0E+10
TAVB=0.0
IMXB=0
IMNB=0
ISMXB=0
ARWB=0.0
DO 206 I=173,196
IF (TMXB.LT.T(I)) THEN
    IMXB=I
    TMXB=T(I)
ENDIF
IF (TMNB.GT.T(I)) THEN
    IMNB=I
    TMNB=T(I)

```

```

        ENDIF
206 CONTINUE
DO 208 I=11,20
IF (TSMXB.LT.T(IB1(I))) THEN
    ISMXB=IB1(I)
    TSMXB=T(ISMXB)
ENDIF
ARWB=ARWB+BA(I)
TAVB=TAVB+BA(I)*T(IB1(I))
208 CONTINUE
TAVB=TAVB/ARWB
TAVBF=TAVB*1.8+32.0
TSMXBF=TSMXB*1.8+32.0
TMXBF=TMXB*1.8+32.0
TMNBF=TMNB*1.8+32.0
WRITE(6,210) TMXB,TMXBF,IMXB,TMNB,TMNBF,IMNB,
1           TSMXB,TSMXBF,ISMXB,TAVB,TAVBF
210 FORMAT(//' UPPER PU BUTTON: '/
1           '      MAX BUTTON T =',
2           F9.4,' C =',F9.4,' F AT NODE',I4/
3           '      MIN BUTTON T =',
4           F9.4,' C =',F9.4,' F AT NODE',I4/
5           '      MAX SURFACE T =',
6           F9.4,' C =',F9.4,' F AT NODE',I4/
7           '      AVE SURFACE T =',F9.4,' C =',F9.4,' F')
C
C CONTAINER OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
QCDB=0.0
QCDS=0.0
QCDT=0.0
DO 220 I=466,471
QCDB=QCDB+G(I)*(T(I-465)-T(143))
220 CONTINUE
QCD=QCDB
QCV=0.0
QCVB=0.0
J=211
DO 230 I=472,512
IF (I.LE.487) THEN
    IF (I.EQ.477) J=212
    IF (I.EQ.482) J=214
    QCV=QCV+G(I)*(T(ISA(I-471))-T(J))
    IF (I.EQ.481) QCVS=QCV
ENDIF
K=I
IF (I.GE.506) K=I+204
H(I-471)=G(K)/AA(I-471)
230 CONTINUE
QCVT=QCV-QCVS
WRITE(6,110)
WRITE(6,120) (I,H(I-471),I=472,505),(I,H(I-675),I=710,716)
QRD=0.0
QRDB=0.0
DO 240 I=532,566
IF (I.LE.550) THEN
    K=I
ELSE

```

```

        K=I+102
      ENDIF
      QRD=QRD+G(K)*((T(IS1(I-531))+273.16)**4
1      -(T(IS2(I-531))+273.16)**4)
      IF (I.EQ.543) QRDT=QRD
240  CONTINUE
      QRDS=QRD-QRDT
      TOT=QCD+QCV+QRD
      FCD=QCD/TOT
      FCDB=QCDB/TOT
      FCDS=QCDS/TOT
      FCDT=QCDT/TOT
      FCV=QCV/TOT
      FCVB=QCVB/TOT
      FCVS=QCVS/TOT
      FCVT=QCVT/TOT
      FRD=QRD/TOT
      FRDB=QRDB/TOT
      FRDS=QRDS/TOT
      FRDT=QRDT/TOT
      WRITE(6,250) QCD,QCDB,QCDS,QCDT,
1          QCV,QCDB,QCDS,QCDT,
2          QRD,QRDB,QRDS,QRDT,
3          TOT,
4          FCD,FCDB,FCDS,FCDT,
5          FCV,FCVB,FCVS,FCVT,
6          FRD,FRDB,FRDS,FRDT
250 FORMAT(' HEAT TRANSFER FROM THE BNFL CONTAINER SURFACE'/
1      ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2      ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3      F10.6,' W, QCDS =',F10.6,' W, QCVT =',F10.6,' W'/
4      ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5      ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6      ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7      ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8      ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9      ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A      F10.6)
C
      TMX=0.0
      TAV=0.0
      ARW=0.0
      DO 260 I=1,21
      IF (TMX.LT.T(ICN(I))) THEN
          IMX=ICN(I)
          TMX=T(IMX)
      ENDIF
      ARW=ARW+ACN(I)
      TAV=TAV+ACN(I)*T(ICN(I))
260  CONTINUE
      TAV=TAV/ARW
      TAVF=TAV*1.8+32.0
      TMXF=TMX*1.8+32.0
      WRITE(6,265) TMX,TMXF,IMX,TAV,TAVF
265 FORMAT(' BNFL CONTAINER OUTSIDE SURFACE:'/
2      ' MAX SURFACE T =',
3      F9.4,' C =',F9.4,' F AT NODE',I4/
4      ' AVE SURFACE T =',F9.4,' C =',F9.4,' F')

```

```

C
C      DRUM OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
QCDB=G(704)*(T(204)-T(224))
QCDS=0.0
QCDT=0.0
QCD=QCDB
QCVB=G(498)*(T(143)-T(218))+G(499)*(T(144)-T(218))
1    +G(500)*(T(146)-T(219))+G(494)*(T(205)-T(219))
QCVS=G(714)*(T(205)-T(220))+G(715)*(T(207)-T(220))
1    +G(716)*(T(208)-T(221))+G(717)*(T(209)-T(222))
QCVT=G(718)*(T(202)-T(223))+G(719)*(T(200)-T(223))
QCV=QCVB+QCVS+QCVT
X=(T(224)+273.16)**4
QRDB=G(750)*((T(143)+273.16)**4-X)
1    +G(749)*((T(144)+273.16)**4-X)
2    +G(748)*((T(146)+273.16)**4-X)
3    +G(747)*((T(205)+273.16)**4-X)
X=(T(207)+273.16)**4
QRDS=G(743)*(X-(T(224)+273.16)**4)
1    +G(744)*(X-(T(225)+273.16)**4)
2    +G(745)*(X-(T(226)+273.16)**4)
3    +G(746)*(X-(T(227)+273.16)**4)
X=(T(208)+273.16)**4
QRDS=QRDS+G(738)*(X-(T(224)+273.16)**4)
1    +G(739)*(X-(T(225)+273.16)**4)
2    +G(740)*(X-(T(226)+273.16)**4)
3    +G(741)*(X-(T(227)+273.16)**4)
4    +G(742)*(X-(T(228)+273.16)**4)
X=(T(209)+273.16)**4
QRDS=QRDS+G(732)*(X-(T(224)+273.16)**4)
1    +G(733)*(X-(T(225)+273.16)**4)
2    +G(734)*(X-(T(226)+273.16)**4)
3    +G(735)*(X-(T(227)+273.16)**4)
4    +G(736)*(X-(T(228)+273.16)**4)
X=(T(200)+273.16)**4
QRDT=G(727)*(X-(T(224)+273.16)**4)
1    +G(728)*(X-(T(228)+273.16)**4)
X=(T(202)+273.16)**4
QRDT=QRDT+G(729)*(X-(T(224)+273.16)**4)
1    +G(730)*(X-(T(228)+273.16)**4)
QRD=QRDB+QRDS+QRDT
TOT=QCD+QCV+QRD
FCD=QCD/TOT
FCDB=QCDB/TOT
FCDS=QCDS/TOT
FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,270) QCD,QCDB,QCDS,QCDT,
1           QCV,QCVB,QCVS,QCWT,
2           QRD,QRDB,QRDS,QRDT,

```

```

3           TOT,
4           FCD,FCDB,FCDS,FCDT,
5           FCV,FCVB,FCVS,FCVT,
6           FRD,FRDB,FRDS,FRDT
270 FORMAT(// HEAT TRANSFER FROM THE DRUM OUTER SURFACE'/
1           ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2           ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3           F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4           ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5           ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6           ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7           ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8           ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9           ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A           F10.6)
C
TMX=0.0
TAV=0.0
ARW=0.0
DO 280 I=1,10
IF (TMX.LT.T(IDM(I))) THEN
  IMX=IDM(I)
  TMX=T(IMX)
ENDIF
ARW=ARW+ADM(I)
TAV=TAV+ADM(I)*T(IDM(I))
280 CONTINUE
TAV=TAV/ARW
TAVF=TAV*1.8+32.0
TMXF=TMX*1.8+32.0
WRITE(6,290) TMX,TMXF,IMX,TAV,TAVF
290 FORMAT(//' STORAGE DRUM OUTSIDE SURFACE:'/
2           ' MAX SURFACE T =',
3           F9.4,' C =',F9.4,' F AT NODE',I4/
4           ' AVE SURFACE T =',F9.4,' C =',F9.4,' F')
C
C CABINET OUTER SURFACE HEAT FLUXES AND TEMPERATURES
C
QCDB=0.0
QCDS=0.0
QCDT=0.0
QCD=0.0
QCVB=0.0
QCVT=0.0
QCVS=G(757)*(T(225)-T(229))+G(758)*(T(226)-T(229))
1   +G(759)*(T(227)-T(229))+G(760)*(T(228)-T(229))
QCV=QCVS
QRDB=0.0
QRDT=0.0
X=(T(229)+273.16)**4
QRDS=G(761)*((T(225)+273.16)**4-X)
1   +G(762)*((T(226)+273.16)**4-X)
2   +G(763)*((T(227)+273.16)**4-X)
3   +G(764)*((T(228)+273.16)**4-X)
QRD=QRDS
TOT=QCD+QCV+QRD
FCD=QCD/TOT
FCDB=QCDB/TOT

```

```

FCDS=QCDS/TOT
FCDT=QCDT/TOT
FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
      WRITE(6,300) QCD,QCDB,QCDS,QCDT,
1           QCV,QCVB,QCVS,QCVT,
2           QRD,QRDB,QRDS,QRDT,
3           TOT,
4           FCD,FCDB,FCDS,FCDT,
5           FCV,FCVB,FCVS,FCVT,
6           FRD,FRDB,FRDS,FRDT
300 FORMAT(//' HEAT TRANSFER FROM THE CABINET DOOR SURFACE'/
1           ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2           ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3           F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4           ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5           ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6           ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7           ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8           ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9           ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A           F10.6)
C
      TMX=0.0
      TAV=0.0
      ARW=0.0
      DO 310 I=1,4
      IF (TMX.LT.T(ICT(I))) THEN
          IMX=ICT(I)
          TMX=T(IMX)
      ENDIF
      ARW=ARW+ACT(I)
      TAV=TAV+ACT(I)*T( ICT(I) )
310 CONTINUE
      TAV=TAV/ARW
      TAVF=TAV*1.8+32.0
      TMXF=TMX*1.8+32.0
      WRITE(6,320) TMX,TMXF,IMX,TAV,TAVF
320 FORMAT(//' CABINET DOOR SURFACE:'/
2           ' MAX SURFACE T =',
3           F9.4,' C =',F9.4,' F AT NODE',I4/
4           ' AVE SURFACE T =',F9.4,' C =',F9.4,' F')
ENDD
USER DATA
ENDD
ENDD

```

## APPENDIX E

### TSAP INPUT DECK FOR PUO<sub>2</sub>—PLATE CASE (4.5 G/CM<sup>3</sup>, 3.0 W/KG, AIR)

```

BNFL Container with BNFL Convenience Jar - on a support plate - 4.5 g/cc in ...
NODE DMOD
COMM
COMM Initial Condition: T = 2.6667E+01 C
COMM
COMM Total Power = 15 W
COMM PuO2 mass = 4.99 kg
COMM Power den = 3.00601202 W/kg
COMM
COMM PuO2 thermal conductivity
COMM      PuO2 maximum density = 11.45 g/cc
COMM PuO2 powder          thermal conductivity (W/m.K)
COMM density (g/cc)   porosity    He           Air        95%N2/O2   Argon
COMM      2.0          8.2533E-01  0.29728403  0.07917497  0.07981482  0.055495...
COMM      2.71929981  7.6251E-01   0.33994471  0.09576562  0.09651579  0.067797...
COMM      3.01560123  7.3663E-01   0.35751793  0.10259981  0.10339543  0.072865...
COMM      4.54048563  6.0345E-01   0.44795672  0.13777126  0.13880077  0.098946...
COMM      6.69915779  4.1492E-01   0.6295129   0.2426644   0.24411061  0.186647...
COMM
COMM Material Properties (used below)
COMM      cp          rho         k          emissivity
COMM      (W.h/kg.K) (kg/m^3)   (W/m.K)   (-)
COMM PuO2 powder    7.8320E-02  4.5405E+03  1.3777E-01  5.0000E-01
COMM SS 304        1.3442E-01  8.0243E+03  1.5130E+01  3.0000E-01
COMM SS 316        1.3119E-01  7.9620E+03  1.3650E+01  3.0000E-01
COMM He            1.4444E+00  1.2100E-01  1.5340E-01
COMM Air           2.7972E-01  9.0880E-01  2.5810E-02
COMM
COMM k(Pu metal) = 6.15856 + 2.11264E-02*TC + 2.0E-05*TC**2
COMM             = 6.5000E+00 W/m.K for TC = 15.92 C (60.66 F)
COMM k(He gas)   = 3.3366E-03*(TC+273.16)**0.668
COMM             = 1.5340E-01 W/m.K for TC = 35.02 C (95.04 F)
COMM
COMM Enhancement Factors - conduction represents convection
COMM                           Enhancement Factor
COMM BNFL Convenience Jar          10
COMM BNFL Inner (open regions only) 5
COMM BNFL Outer (open regions only) 5
COMM Drum                         5
COMM Cabinet Side                  10
COMM Cabinet Top                   2
COMM Bulk Air                      1000
COMM
COMM Contact HTCs (W/m^2.K) -- resistance = 1/HTC
COMM
COMM                                         Ring 1  Ring 2  Ring 3  Ring 4  ...
COMM BNFL jar to BNFL inner (c256-259)  1892.8  1892.8  1892.8  1892.8
COMM BNFL in to out (c400-403)          1892.8  1892.8  1892.8  1892.8
COMM BNFL outb to ??? (n166-170)       1892.8  1892.8  1892.8  1892.8  ...
COMM
COMM Radiation Heat Transfer
COMM          Eff.Emissivity
COMM PuO2 & SS3316      0.23077

```

COMM SS304 & SS304 0.17647  
 COMM SS304 & SS316 0.17647  
 COMM SS316 & SS316 0.17647  
 COMM  
 COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)  
 COMM  
 COMM Nodes defining the interior of the BNFL convenience jar  
 0001,2.6667E+01,7.8320E-02,4.5405E+03,1.4530E-06,1.9831E-02  
 0002,2.6667E+01,7.8320E-02,4.5405E+03,1.1624E-05,1.5865E-01  
 0003,2.6667E+01,7.8320E-02,4.5405E+03,2.3248E-05,3.1730E-01  
 0004,2.6667E+01,7.8320E-02,4.5405E+03,4.5406E-05,6.1973E-01  
 0005,2.6667E+01,7.8320E-02,4.5405E+03,7.2983E-05,9.9613E-01  
 0006,2.6667E+01,7.8320E-02,4.5405E+03,1.6258E-06,2.2190E-02  
 0007,2.6667E+01,7.8320E-02,4.5405E+03,1.3006E-05,1.7752E-01  
 0008,2.6667E+01,7.8320E-02,4.5405E+03,2.6012E-05,3.5504E-01  
 0009,2.6667E+01,7.8320E-02,4.5405E+03,5.0805E-05,6.9343E-01  
 0010,2.6667E+01,7.8320E-02,4.5405E+03,1.0527E-04,1.4368E+00  
 0011,2.6667E+01,7.8320E-02,4.5405E+03,1.6258E-06,2.2190E-02  
 0012,2.6667E+01,7.8320E-02,4.5405E+03,1.3006E-05,1.7752E-01  
 0013,2.6667E+01,7.8320E-02,4.5405E+03,2.6012E-05,3.5504E-01  
 0014,2.6667E+01,7.8320E-02,4.5405E+03,5.0805E-05,6.9343E-01  
 0015,2.6667E+01,7.8320E-02,4.5405E+03,1.0527E-04,1.4368E+00  
 0016,2.6667E+01,7.8320E-02,4.5405E+03,1.6258E-06,2.2190E-02  
 0017,2.6667E+01,7.8320E-02,4.5405E+03,1.3006E-05,1.7752E-01  
 0018,2.6667E+01,7.8320E-02,4.5405E+03,2.6012E-05,3.5504E-01  
 0019,2.6667E+01,7.8320E-02,4.5405E+03,5.0805E-05,6.9343E-01  
 0020,2.6667E+01,7.8320E-02,4.5405E+03,1.0527E-04,1.4368E+00  
 0021,2.6667E+01,2.7972E-01,4.5405E+03,1.6258E-06,2.2190E-02  
 0022,2.6667E+01,2.7972E-01,4.5405E+03,1.3006E-05,1.7752E-01  
 0023,2.6667E+01,2.7972E-01,4.5405E+03,2.6012E-05,3.5504E-01  
 0024,2.6667E+01,2.7972E-01,4.5405E+03,5.0805E-05,6.9343E-01  
 0025,2.6667E+01,2.7972E-01,4.5405E+03,1.0527E-04,1.4368E+00  
 0026,2.6667E+01,2.7972E-01,4.5405E+03,1.3009E-06,1.7756E-02  
 0027,2.6667E+01,2.7972E-01,4.5405E+03,1.0407E-05,1.4205E-01  
 0028,2.6667E+01,2.7972E-01,4.5405E+03,2.0815E-05,2.8410E-01  
 0029,2.6667E+01,2.7972E-01,4.5405E+03,4.0654E-05,5.5488E-01  
 0030,2.6667E+01,2.7972E-01,4.5405E+03,8.4235E-05,1.1497E+00  
 0031,2.6667E+01,2.7972E-01,9.0880E-01,1.5001E-06,0.0000E+00  
 0032,2.6667E+01,2.7972E-01,9.0880E-01,1.2001E-05,0.0000E+00  
 0033,2.6667E+01,2.7972E-01,9.0880E-01,2.4002E-05,0.0000E+00  
 0034,2.6667E+01,2.7972E-01,9.0880E-01,4.6878E-05,0.0000E+00  
 0035,2.6667E+01,2.7972E-01,9.0880E-01,9.7132E-05,0.0000E+00  
 0036,2.6667E+01,2.7972E-01,9.0880E-01,1.6207E-06,0.0000E+00  
 0037,2.6667E+01,2.7972E-01,9.0880E-01,1.2966E-05,0.0000E+00  
 0038,2.6667E+01,2.7972E-01,9.0880E-01,2.5932E-05,0.0000E+00  
 0039,2.6667E+01,2.7972E-01,9.0880E-01,5.0648E-05,0.0000E+00  
 0040,2.6667E+01,2.7972E-01,9.0880E-01,1.0494E-04,0.0000E+00  
 0041,2.6667E+01,2.7972E-01,9.0880E-01,1.6258E-06,0.0000E+00  
 0042,2.6667E+01,2.7972E-01,9.0880E-01,1.3006E-05,0.0000E+00  
 0043,2.6667E+01,2.7972E-01,9.0880E-01,2.6012E-05,0.0000E+00  
 0044,2.6667E+01,2.7972E-01,9.0880E-01,5.0805E-05,0.0000E+00  
 0045,2.6667E+01,2.7972E-01,9.0880E-01,8.6653E-05,0.0000E+00  
 0046,2.6667E+01,2.7972E-01,9.0880E-01,1.1074E-06,0.0000E+00  
 0047,2.6667E+01,2.7972E-01,9.0880E-01,8.8593E-06,0.0000E+00  
 0048,2.6667E+01,2.7972E-01,9.0880E-01,1.7719E-05,0.0000E+00  
 0049,2.6667E+01,2.7972E-01,9.0880E-01,3.4607E-05,0.0000E+00  
 0050,2.6667E+01,2.7972E-01,9.0880E-01,2.8311E-05,0.0000E+00

0051,2.6667E+01,2.7972E-01,9.0880E-01,1.1074E-06,0.0000E+00  
 0052,2.6667E+01,2.7972E-01,9.0880E-01,8.8593E-06,0.0000E+00  
 0053,2.6667E+01,2.7972E-01,9.0880E-01,1.7719E-05,0.0000E+00  
 0054,2.6667E+01,2.7972E-01,9.0880E-01,3.4607E-05,0.0000E+00  
 0055,2.6667E+01,2.7972E-01,9.0880E-01,2.7408E-05,0.0000E+00  
 0056,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0057,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0058,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0059,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0060,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0061,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0062,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0063,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0064,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0065,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0066,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0067,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0068,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0069,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0070,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

COMM

COMM Totals = 1.8350E-03,1.5000E+01

COMM Total Mass = 4.9906689 kg

COMM

COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)

COMM

COMM Nodes defining the BNFL convenience jar wall

0071,2.6667E+01,1.3119E-01,7.9620E+03,7.8540E-08,0.0000E+00  
 0072,2.6667E+01,1.3119E-01,7.9620E+03,6.2832E-07,0.0000E+00  
 0073,2.6667E+01,1.3119E-01,7.9620E+03,1.2566E-06,0.0000E+00  
 0074,2.6667E+01,1.3119E-01,7.9620E+03,2.4544E-06,0.0000E+00  
 0075,2.6667E+01,1.3119E-01,7.9620E+03,4.0835E-06,0.0000E+00  
 0076,2.6667E+01,1.3119E-01,7.9620E+03,4.9634E-06,0.0000E+00  
 0077,2.6667E+01,1.3119E-01,7.9620E+03,7.2184E-06,0.0000E+00  
 0078,2.6667E+01,1.3119E-01,7.9620E+03,7.2184E-06,0.0000E+00  
 0079,2.6667E+01,1.3119E-01,7.9620E+03,7.2184E-06,0.0000E+00  
 0080,2.6667E+01,1.3119E-01,7.9620E+03,7.2184E-06,0.0000E+00  
 0081,2.6667E+01,1.3119E-01,7.9620E+03,5.7761E-06,0.0000E+00  
 0082,2.6667E+01,1.3119E-01,7.9620E+03,6.6605E-06,0.0000E+00  
 0083,2.6667E+01,1.3119E-01,7.9620E+03,7.1961E-06,0.0000E+00  
 0084,2.6667E+01,1.3119E-01,7.9620E+03,2.5834E-05,0.0000E+00  
 0085,2.6667E+01,1.3119E-01,7.9620E+03,3.7450E-05,0.0000E+00  
 0086,2.6667E+01,1.3119E-01,7.9620E+03,2.4642E-05,0.0000E+00  
 0087,2.6667E+01,1.3119E-01,7.9620E+03,5.7176E-05,0.0000E+00  
 0088,2.6667E+01,1.3119E-01,7.9620E+03,1.4726E-05,0.0000E+00  
 0089,2.6667E+01,1.3119E-01,7.9620E+03,7.5398E-06,0.0000E+00  
 0090,2.6667E+01,1.3119E-01,7.9620E+03,3.7699E-06,0.0000E+00  
 0091,2.6667E+01,1.3119E-01,7.9620E+03,4.7124E-07,0.0000E+00

COMM

COMM Totals = 2.3358E-04,0.0000E+00

COMM Total Mass = 1.85977654 kg

COMM

COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)

COMM

COMM Nodes defining the gas space between the BNFL convenience jar and inner...

0092,2.6667E+01,2.7972E-01,9.0880E-01,5.2474E-07,0.0000E+00

0093,2.6667E+01,2.7972E-01,9.0880E-01,3.3419E-06,0.0000E+00  
 0094,2.6667E+01,2.7972E-01,9.0880E-01,7.3485E-06,0.0000E+00  
 0095,2.6667E+01,2.7972E-01,9.0880E-01,7.3485E-06,0.0000E+00  
 0096,2.6667E+01,2.7972E-01,9.0880E-01,7.3485E-06,0.0000E+00  
 0097,2.6667E+01,2.7972E-01,9.0880E-01,7.3485E-06,0.0000E+00  
 0098,2.6667E+01,2.7972E-01,9.0880E-01,5.8802E-06,0.0000E+00  
 0099,2.6667E+01,2.7972E-01,9.0880E-01,6.7805E-06,0.0000E+00  
 0100,2.6667E+01,2.7972E-01,9.0880E-01,7.3258E-06,0.0000E+00  
 0101,2.6667E+01,2.7972E-01,9.0880E-01,7.3485E-06,0.0000E+00  
 0102,2.6667E+01,2.7972E-01,9.0880E-01,1.5866E-05,0.0000E+00  
 0103,2.6667E+01,2.7972E-01,9.0880E-01,7.1355E-06,0.0000E+00  
 0104,2.6667E+01,2.7972E-01,9.0880E-01,1.1067E-05,0.0000E+00  
 0105,2.6667E+01,2.7972E-01,9.0880E-01,2.9457E-05,0.0000E+00  
 0106,2.6667E+01,2.7972E-01,9.0880E-01,1.7181E-05,0.0000E+00  
 0107,2.6667E+01,2.7972E-01,9.0880E-01,8.7965E-06,0.0000E+00  
 0108,2.6667E+01,2.7972E-01,9.0880E-01,4.3982E-06,0.0000E+00  
 0109,2.6667E+01,2.7972E-01,9.0880E-01,5.4978E-07,0.0000E+00

COMM

COMM Totals = 1.5505E-04,0.0000E+00

COMM Total Mass = 0.00014091 kg

COMM

COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K) , (kg/m^3) , (m^3) , (W)

COMM

COMM Nodes defining the BNFL inner container wall

0110,2.6667E+01,1.3119E-01,7.9620E+03,1.1781E-07,0.0000E+00  
 0111,2.6667E+01,1.3119E-01,7.9620E+03,9.4248E-07,0.0000E+00  
 0112,2.6667E+01,1.3119E-01,7.9620E+03,1.8850E-06,0.0000E+00  
 0113,2.6667E+01,1.3119E-01,7.9620E+03,3.6816E-06,0.0000E+00  
 0114,2.6667E+01,1.3119E-01,7.9620E+03,7.3917E-06,0.0000E+00  
 0115,2.6667E+01,1.3119E-01,7.9620E+03,7.7169E-06,0.0000E+00  
 0116,2.6667E+01,1.3119E-01,7.9620E+03,1.1267E-05,0.0000E+00  
 0117,2.6667E+01,1.3119E-01,7.9620E+03,1.1267E-05,0.0000E+00  
 0118,2.6667E+01,1.3119E-01,7.9620E+03,1.1267E-05,0.0000E+00  
 0119,2.6667E+01,1.3119E-01,7.9620E+03,1.1267E-05,0.0000E+00  
 0120,2.6667E+01,1.3119E-01,7.9620E+03,9.0155E-06,0.0000E+00  
 0121,2.6667E+01,1.3119E-01,7.9620E+03,1.0396E-05,0.0000E+00  
 0122,2.6667E+01,1.3119E-01,7.9620E+03,1.1232E-05,0.0000E+00  
 0123,2.6667E+01,1.3119E-01,7.9620E+03,1.1267E-05,0.0000E+00  
 0124,2.6667E+01,1.3119E-01,7.9620E+03,7.6744E-06,0.0000E+00  
 0125,2.6667E+01,1.3119E-01,7.9620E+03,1.0940E-05,0.0000E+00  
 0126,2.6667E+01,1.3119E-01,7.9620E+03,3.8100E-06,0.0000E+00  
 0127,2.6667E+01,1.3119E-01,7.9620E+03,9.6698E-06,0.0000E+00  
 0128,2.6667E+01,1.3119E-01,7.9620E+03,7.8885E-06,0.0000E+00  
 0129,2.6667E+01,1.3119E-01,7.9620E+03,3.6816E-06,0.0000E+00  
 0130,2.6667E+01,1.3119E-01,7.9620E+03,1.8850E-06,0.0000E+00  
 0131,2.6667E+01,1.3119E-01,7.9620E+03,9.4248E-07,0.0000E+00  
 0132,2.6667E+01,1.3119E-01,7.9620E+03,1.1781E-07,0.0000E+00  
 0133,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0134,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0135,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0136,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00

COMM

COMM Totals =,,,1.5532E-04,0.0000E+00

COMM Total Mass =,1.23666607,kg

COMM

COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K) , (kg/m^3) , (m^3) , (W)

COMM

COMM Nodes defining the gas space between the BNFL inner and outer containers

0137,2.6667E+01,2.7972E-01,9.0880E-01,8.8042E-06,0.0000E+00  
 0138,2.6667E+01,2.7972E-01,9.0880E-01,2.9010E-05,0.0000E+00  
 0139,2.6667E+01,2.7972E-01,9.0880E-01,7.6737E-06,0.0000E+00  
 0140,2.6667E+01,2.7972E-01,9.0880E-01,7.6737E-06,0.0000E+00  
 0141,2.6667E+01,2.7972E-01,9.0880E-01,7.6737E-06,0.0000E+00  
 0142,2.6667E+01,2.7972E-01,9.0880E-01,7.6737E-06,0.0000E+00  
 0143,2.6667E+01,2.7972E-01,9.0880E-01,6.1404E-06,0.0000E+00  
 0144,2.6667E+01,2.7972E-01,9.0880E-01,7.0805E-06,0.0000E+00  
 0145,2.6667E+01,2.7972E-01,9.0880E-01,7.6499E-06,0.0000E+00  
 0146,2.6667E+01,2.7972E-01,9.0880E-01,7.6737E-06,0.0000E+00  
 0147,2.6667E+01,2.7972E-01,9.0880E-01,5.2270E-06,0.0000E+00  
 0148,2.6667E+01,2.7972E-01,9.0880E-01,7.4512E-06,0.0000E+00  
 0149,2.6667E+01,2.7972E-01,9.0880E-01,2.5950E-06,0.0000E+00  
 0150,2.6667E+01,2.7972E-01,9.0880E-01,3.3364E-06,0.0000E+00  
 0151,2.6667E+01,2.7972E-01,9.0880E-01,1.7865E-05,0.0000E+00  
 0152,2.6667E+01,2.7972E-01,9.0880E-01,4.8394E-05,0.0000E+00  
 0153,2.6667E+01,2.7972E-01,9.0880E-01,2.8225E-05,0.0000E+00  
 0154,2.6667E+01,2.7972E-01,9.0880E-01,1.4451E-05,0.0000E+00  
 0155,2.6667E+01,2.7972E-01,9.0880E-01,7.2257E-06,0.0000E+00  
 0156,2.6667E+01,2.7972E-01,9.0880E-01,9.0321E-07,0.0000E+00

COMM

COMM Totals = 2.3273E-04,0.0000E+00

COMM Total Mass = 0.0002115 kg

COMM

COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER  
 COMM , (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)

COMM

COMM Nodes defining the BNFL outer container wall

0157,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0158,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0159,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0160,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0161,2.6667E+01,1.3119E-01,7.9620E+03,7.0686E-07,0.0000E+00  
 0162,2.6667E+01,1.3119E-01,7.9620E+03,5.6549E-06,0.0000E+00  
 0163,2.6667E+01,1.3119E-01,7.9620E+03,1.1310E-05,0.0000E+00  
 0164,2.6667E+01,1.3119E-01,7.9620E+03,2.2089E-05,0.0000E+00  
 0165,2.6667E+01,1.3119E-01,7.9620E+03,3.7874E-05,0.0000E+00  
 0166,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0167,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0168,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0169,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0170,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0171,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00  
 0172,2.6667E+01,1.3119E-01,7.9620E+03,3.2062E-05,0.0000E+00  
 0173,2.6667E+01,1.3119E-01,7.9620E+03,2.6114E-05,0.0000E+00  
 0174,2.6667E+01,1.3119E-01,7.9620E+03,4.7603E-05,0.0000E+00  
 0175,2.6667E+01,1.3119E-01,7.9620E+03,4.7603E-05,0.0000E+00  
 0176,2.6667E+01,1.3119E-01,7.9620E+03,1.9046E-05,0.0000E+00  
 0177,2.6667E+01,1.3119E-01,7.9620E+03,2.1962E-05,0.0000E+00  
 0178,2.6667E+01,1.3119E-01,7.9620E+03,4.7529E-05,0.0000E+00  
 0179,2.6667E+01,1.3119E-01,7.9620E+03,4.7373E-05,0.0000E+00  
 0180,2.6667E+01,1.3119E-01,7.9620E+03,1.4948E-05,0.0000E+00  
 0181,2.6667E+01,1.3119E-01,7.9620E+03,3.6458E-05,0.0000E+00  
 0182,2.6667E+01,1.3119E-01,7.9620E+03,4.2082E-05,0.0000E+00  
 0183,2.6667E+01,1.3119E-01,7.9620E+03,2.4544E-05,0.0000E+00  
 0184,2.6667E+01,1.3119E-01,7.9620E+03,1.2566E-05,0.0000E+00

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0185,2.6667E+01,1.3119E-01,7.9620E+03,6.2832E-06,0.0000E+00
0186,2.6667E+01,1.3119E-01,7.9620E+03,7.8540E-07,0.0000E+00
COMM
COMM Totals = 5.0459E-04,0.0000E+00
COMM Total Mass = 4.01755515 kg
COMM
COMM Container assembly totals = 3.1163E-03,1.5000E+01
COMM Total Mass = 12.1050191
COMM
COMM
COMM N#, TEMP , SP.HEAT , DENSITY , VOLUME , POWER
COMM , (C) ,(W.h/kg.K), (kg/m^3) , (m^3) , (W)
COMM Support plate nodes
0187,2.6667E+01,1.3119E-01,7.9620E+03,9.3511E-06,0.0000E+00
0188,2.6667E+01,1.3119E-01,7.9620E+03,4.9094E-05,0.0000E+00
0189,2.6667E+01,1.3119E-01,7.9620E+03,9.1174E-05,0.0000E+00
0190,2.6667E+01,1.3119E-01,7.9620E+03,2.3340E-04,0.0000E+00
0191,2.6667E+01,1.3119E-01,7.9620E+03,4.7422E-04,0.0000E+00
COMM
COMM Boundary Temperature Node for support plate calculation
COMM
-192,2.6667E+01,0.0000E+00,0.0000E+00,0.0000E+00,0.0000E+00
ENDD
COND DMOD
COMM Axial conduction and convection paths for inside the convenience jar
COMM C#, N1, N2, K or H , AREA , DX or 1
COMM (m^2) , (m or -)
0001,0001,0071,1.3777E-01,7.8540E-05,9.2500E-03
0002,0002,0072,1.3777E-01,6.2832E-04,9.2500E-03
0003,0003,0073,1.3777E-01,1.2566E-03,9.2500E-03
0004,0004,0074,1.3777E-01,2.4544E-03,9.2500E-03
0005,0005,0075,1.3777E-01,3.8021E-03,9.5979E-03
0006,0001,0006,1.3777E-01,7.8540E-05,1.9600E-02
0007,0002,0007,1.3777E-01,6.2832E-04,1.9600E-02
0008,0003,0008,1.3777E-01,1.2566E-03,1.9600E-02
0009,0004,0009,1.3777E-01,2.4544E-03,1.9600E-02
0010,0005,0010,1.3777E-01,5.0855E-03,1.7526E-02
0011,0006,0011,1.3777E-01,7.8540E-05,2.0700E-02
0012,0007,0012,1.3777E-01,6.2832E-04,2.0700E-02
0013,0008,0013,1.3777E-01,1.2566E-03,2.0700E-02
0014,0009,0014,1.3777E-01,2.4544E-03,2.0700E-02
0015,0010,0015,1.3777E-01,5.0855E-03,2.0700E-02
0016,0011,0016,1.3777E-01,7.8540E-05,2.0700E-02
0017,0012,0017,1.3777E-01,6.2832E-04,2.0700E-02
0018,0013,0018,1.3777E-01,1.2566E-03,2.0700E-02
0019,0014,0019,1.3777E-01,2.4544E-03,2.0700E-02
0020,0015,0020,1.3777E-01,5.0855E-03,2.0700E-02
0021,0016,0056,1.3777E-01,7.8540E-05,1.0350E-02
0022,0017,0057,1.3777E-01,6.2832E-04,1.0350E-02
0023,0018,0058,1.3777E-01,1.2566E-03,1.0350E-02
0024,0019,0059,1.3777E-01,2.4544E-03,1.0350E-02
0025,0020,0060,1.3777E-01,5.0855E-03,1.0350E-02
0026,0056,0021,1.3777E-01,7.8540E-05,1.0350E-02
0027,0057,0022,1.3777E-01,6.2832E-04,1.0350E-02
0028,0058,0023,1.3777E-01,1.2566E-03,1.0350E-02
0029,0059,0024,1.3777E-01,2.4544E-03,1.0350E-02
0030,0060,0025,1.3777E-01,5.0855E-03,1.0350E-02
0031,0021,0026,1.3777E-01,7.8540E-05,1.8632E-02

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0032,0022,0027,1.3777E-01,6.2832E-04,1.8632E-02  
 0033,0023,0028,1.3777E-01,1.2566E-03,1.8632E-02  
 0034,0024,0029,1.3777E-01,2.4544E-03,1.8632E-02  
 0035,0025,0030,1.3777E-01,5.0855E-03,1.8632E-02  
 0036,0026,0061,1.3777E-01,7.8540E-05,8.2820E-03  
 0037,0027,0062,1.3777E-01,6.2832E-04,8.2820E-03  
 0038,0028,0063,1.3777E-01,1.2566E-03,8.2820E-03  
 0039,0029,0064,1.3777E-01,2.4544E-03,8.2820E-03  
 0040,0030,0065,1.3777E-01,5.0855E-03,8.2820E-03  
 0041,0061,0031,2.5810E-02,7.8540E-05,9.5500E-03  
 0042,0062,0032,2.5810E-02,6.2832E-04,9.5500E-03  
 0043,0063,0033,2.5810E-02,1.2566E-03,9.5500E-03  
 0044,0064,0034,2.5810E-02,2.4544E-03,9.5500E-03  
 0045,0065,0035,2.5810E-02,5.0855E-03,9.5500E-03  
 0046,0031,0036,2.5810E-01,7.8540E-05,1.9868E-02  
 0047,0032,0037,2.5810E-01,6.2832E-04,1.9868E-02  
 0048,0033,0038,2.5810E-01,1.2566E-03,1.9868E-02  
 0049,0034,0039,2.5810E-01,2.4544E-03,1.9868E-02  
 0050,0035,0040,2.5810E-01,5.0855E-03,1.9868E-02  
 0051,0036,0041,2.5810E-01,7.8540E-05,2.0668E-02  
 0052,0037,0042,2.5810E-01,6.2832E-04,2.0668E-02  
 0053,0038,0043,2.5810E-01,1.2566E-03,2.0668E-02  
 0054,0039,0044,2.5810E-01,2.4544E-03,2.0668E-02  
 0055,0040,0045,2.5810E-01,5.0855E-03,2.0668E-02  
 0056,0041,0066,2.5810E-01,7.8540E-05,1.0350E-02  
 0057,0042,0067,2.5810E-01,6.2832E-04,1.0350E-02  
 0058,0043,0068,2.5810E-01,1.2566E-03,1.0350E-02  
 0059,0044,0069,2.5810E-01,2.4544E-03,1.0350E-02  
 0060,0045,0070,2.5810E-01,2.4946E-03,1.0350E-02  
 0061,0066,0046,2.5810E-01,7.8540E-05,7.0500E-03  
 0062,0067,0047,2.5810E-01,6.2832E-04,7.0500E-03  
 0063,0068,0048,2.5810E-01,1.2566E-03,7.0500E-03  
 0064,0069,0049,2.5810E-01,2.4544E-03,7.0500E-03  
 0065,0070,0050,2.5810E-01,2.4946E-03,7.0500E-03  
 0066,0046,0051,2.5810E-01,7.8540E-05,1.4100E-02  
 0067,0047,0052,2.5810E-01,6.2832E-04,1.4100E-02  
 0068,0048,0053,2.5810E-01,1.2566E-03,1.4100E-02  
 0069,0049,0054,2.5810E-01,2.4544E-03,1.4100E-02  
 0070,0050,0055,2.5810E-01,1.9439E-03,1.4100E-02  
 0071,0051,0091,2.5810E-02,7.8540E-05,7.0500E-03  
 0072,0052,0090,2.5810E-02,6.2832E-04,7.0500E-03  
 0073,0053,0089,2.5810E-02,1.2566E-03,7.0500E-03  
 0074,0054,0088,2.5810E-02,2.4544E-03,7.0500E-03  
 0075,0055,0087,2.5810E-02,1.9439E-03,7.0500E-03

COMM

COMM Radial conduction and convection paths for inside the convenience jar

COMM C#, N1, N2, K or H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)

0076,0001,0002,1.3777E-01,5.8119E-04,5.7565E-03  
 0077,0006,0007,1.3777E-01,6.5031E-04,5.7565E-03  
 0078,0011,0012,1.3777E-01,6.5031E-04,5.7565E-03  
 0079,0016,0017,1.3777E-01,6.5031E-04,5.7565E-03  
 0080,0021,0022,1.3777E-01,6.5031E-04,5.7565E-03  
 0081,0026,0027,1.3777E-01,5.2037E-04,5.7565E-03  
 0082,0031,0032,2.5810E-01,6.0004E-04,5.7565E-03  
 0083,0036,0037,2.5810E-01,6.4830E-04,5.7565E-03  
 0084,0041,0042,2.5810E-01,6.5031E-04,5.7565E-03  
 0085,0046,0047,2.5810E-01,4.4296E-04,5.7565E-03

0086,0051,0052,2.5810E-01,4.4296E-04,5.7565E-03  
 0087,0002,0003,1.3777E-01,1.7436E-03,9.1783E-03  
 0088,0007,0008,1.3777E-01,1.9509E-03,9.1783E-03  
 0089,0012,0013,1.3777E-01,1.9509E-03,9.1783E-03  
 0090,0017,0018,1.3777E-01,1.9509E-03,9.1783E-03  
 0091,0022,0023,1.3777E-01,1.9509E-03,9.1783E-03  
 0092,0027,0028,1.3777E-01,1.5611E-03,9.1783E-03  
 0093,0032,0033,2.5810E-01,1.8001E-03,9.1783E-03  
 0094,0037,0038,2.5810E-01,1.9449E-03,9.1783E-03  
 0095,0042,0043,2.5810E-01,1.9509E-03,9.1783E-03  
 0096,0047,0048,2.5810E-01,1.3289E-03,9.1783E-03  
 0097,0052,0053,2.5810E-01,1.3289E-03,9.1783E-03  
 0098,0003,0004,1.3777E-01,2.9060E-03,1.0890E-02  
 0099,0008,0009,1.3777E-01,3.2515E-03,1.0890E-02  
 0100,0013,0014,1.3777E-01,3.2515E-03,1.0890E-02  
 0101,0018,0019,1.3777E-01,3.2515E-03,1.0890E-02  
 0102,0023,0024,1.3777E-01,3.2515E-03,1.0890E-02  
 0103,0028,0029,1.3777E-01,2.6019E-03,1.0890E-02  
 0104,0033,0034,2.5810E-01,3.0002E-03,1.0890E-02  
 0105,0038,0039,2.5810E-01,3.2415E-03,1.0890E-02  
 0106,0043,0044,2.5810E-01,3.2515E-03,1.0890E-02  
 0107,0048,0049,2.5810E-01,2.2148E-03,1.0890E-02  
 0108,0053,0054,2.5810E-01,2.2148E-03,1.0890E-02  
 0109,0004,0005,1.3777E-01,4.3590E-03,1.3023E-02  
 0110,0009,0010,1.3777E-01,4.8773E-03,1.4626E-02  
 0111,0014,0015,1.3777E-01,4.8773E-03,1.4626E-02  
 0112,0019,0020,1.3777E-01,4.8773E-03,1.4626E-02  
 0113,0024,0025,1.3777E-01,4.8773E-03,1.4626E-02  
 0114,0029,0030,1.3777E-01,3.9028E-03,1.4626E-02  
 0115,0034,0035,2.5810E-01,4.5003E-03,1.4626E-02  
 0116,0039,0040,2.5810E-01,4.8622E-03,1.4626E-02  
 0117,0044,0045,2.5810E-01,4.8773E-03,1.3373E-02  
 0118,0049,0050,2.5810E-01,3.3222E-03,9.9411E-03  
 0119,0054,0055,2.5810E-01,3.3222E-03,9.8301E-03  
 0120,0005,0076,1.3777E-01,4.9447E-03,6.9398E-03  
 0121,0010,0077,1.3777E-01,7.1534E-03,8.5629E-03  
 0122,0015,0078,1.3777E-01,7.1534E-03,8.5629E-03  
 0123,0020,0079,1.3777E-01,7.1534E-03,8.5629E-03  
 0124,0025,0080,1.3777E-01,7.1534E-03,8.5629E-03  
 0125,0030,0081,1.3777E-01,5.7241E-03,8.5629E-03  
 0126,0035,0082,2.5810E-02,6.6005E-03,8.5629E-03  
 0127,0040,0083,2.5810E-02,7.1313E-03,8.5629E-03  
 0128,0045,0084,2.5810E-02,7.4924E-03,7.2938E-03  
 0129,0050,0085,2.5810E-02,4.1542E-03,3.8415E-03

COMM NODE 87 WRAPS THE INTERIOR CORNER FROM THE TOP OF THE  
 COMM CONVENIENCE JAR TO THE SIDE. NODE 87 SHIELDS NODE 86  
 COMM FROM THE INTERIOR OF THE CONVENIENCE JAR.

0130,0055,0087,2.5810E-02,3.9867E-03,3.7303E-03

COMM

COMM Radiation paths for inside the convenience jar  
 COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT  
 COMM (m^2) , (-)  
 -131,0056,0080,0.0000E+00,7.8540E-05,0.0000E+00  
 -132,0056,0081,0.0000E+00,7.8540E-05,0.0000E+00  
 -133,0061,0082,2.3077E-01,7.8540E-05,1.0833E-01  
 -134,0061,0083,2.3077E-01,7.8540E-05,2.3590E-01  
 -135,0061,0084,2.3077E-01,7.8540E-05,2.9043E-01  
 -136,0061,0085,2.3077E-01,7.8540E-05,9.8850E-02

-137,0061,0087,2.3077E-01,7.8540E-05,6.1950E-02  
-138,0061,0087,2.3077E-01,7.8540E-05,5.3040E-02  
-139,0061,0088,2.3077E-01,7.8540E-05,7.7990E-02  
-140,0061,0089,2.3077E-01,7.8540E-05,4.5740E-02  
-141,0061,0090,2.3077E-01,7.8540E-05,2.7770E-02  
-142,0057,0080,0.0000E+00,6.2832E-04,0.0000E+00  
-143,0057,0081,0.0000E+00,6.2832E-04,0.0000E+00  
-144,0062,0082,2.3077E-01,6.2832E-04,1.1507E-01  
-145,0062,0083,2.3077E-01,6.2832E-04,2.4033E-01  
-146,0062,0084,2.3077E-01,6.2832E-04,2.8820E-01  
-147,0062,0085,2.3077E-01,6.2832E-04,9.5620E-02  
-148,0062,0087,2.3077E-01,6.2832E-04,5.9890E-02  
-149,0062,0087,2.3077E-01,6.2832E-04,5.2460E-02  
-150,0062,0088,2.3077E-01,6.2832E-04,7.6690E-02  
-151,0062,0089,2.3077E-01,6.2832E-04,4.4700E-02  
-152,0062,0090,2.3077E-01,6.2832E-04,2.7040E-02  
-153,0058,0080,0.0000E+00,1.2566E-03,0.0000E+00  
-154,0058,0081,0.0000E+00,1.2566E-03,0.0000E+00  
-155,0063,0082,2.3077E-01,1.2566E-03,1.3603E-01  
-156,0063,0083,2.3077E-01,1.2566E-03,2.5037E-01  
-157,0063,0084,2.3077E-01,1.2566E-03,2.8033E-01  
-158,0063,0085,2.3077E-01,1.2566E-03,8.7170E-02  
-159,0063,0087,2.3077E-01,1.2566E-03,5.4610E-02  
-160,0063,0087,2.3077E-01,1.2566E-03,5.0890E-02  
-161,0063,0088,2.3077E-01,1.2566E-03,7.3300E-02  
-162,0063,0089,2.3077E-01,1.2566E-03,4.2090E-02  
-163,0063,0090,2.3077E-01,1.2566E-03,2.5210E-02  
-164,0059,0080,0.0000E+00,2.4544E-03,0.0000E+00  
-165,0059,0081,0.0000E+00,2.4544E-03,0.0000E+00  
-166,0064,0082,2.3077E-01,2.4544E-03,1.9386E-01  
-167,0064,0083,2.3077E-01,2.4544E-03,2.5740E-01  
-168,0064,0084,2.3077E-01,2.4544E-03,2.5747E-01  
-169,0064,0085,2.3077E-01,2.4544E-03,7.1580E-02  
-170,0064,0087,2.3077E-01,2.4544E-03,4.5230E-02  
-171,0064,0087,2.3077E-01,2.4544E-03,4.7770E-02  
-172,0064,0088,2.3077E-01,2.4544E-03,6.7050E-02  
-173,0064,0089,2.3077E-01,2.4544E-03,3.7530E-02  
-174,0064,0090,2.3077E-01,2.4544E-03,2.2130E-02  
-175,0060,0080,0.0000E+00,5.0855E-03,0.0000E+00  
-176,0060,0081,0.0000E+00,5.0855E-03,0.0000E+00  
-177,0065,0082,2.3077E-01,5.0855E-03,4.0313E-01  
-178,0065,0083,2.3077E-01,5.0855E-03,1.8230E-01  
-179,0065,0084,2.3077E-01,5.0855E-03,1.9315E-01  
-180,0065,0085,2.3077E-01,5.0855E-03,4.6980E-02  
-181,0065,0087,2.3077E-01,5.0855E-03,3.0850E-02  
-182,0065,0087,2.3077E-01,5.0855E-03,4.0030E-02  
-183,0065,0088,2.3077E-01,5.0855E-03,5.6040E-02  
-184,0065,0089,2.3077E-01,5.0855E-03,3.0150E-02  
-185,0065,0090,2.3077E-01,5.0855E-03,1.7370E-02  
-186,0080,0081,0.0000E+00,7.1534E-03,0.0000E+00  
-187,0080,0082,0.0000E+00,7.1534E-03,0.0000E+00  
-188,0080,0083,0.0000E+00,7.1534E-03,0.0000E+00  
-189,0080,0084,0.0000E+00,7.1534E-03,0.0000E+00  
-190,0080,0085,0.0000E+00,7.1534E-03,0.0000E+00  
-191,0080,0087,0.0000E+00,7.1534E-03,0.0000E+00  
-192,0080,0087,0.0000E+00,7.1534E-03,0.0000E+00  
-193,0080,0088,0.0000E+00,7.1534E-03,0.0000E+00  
-194,0080,0089,0.0000E+00,7.1534E-03,0.0000E+00

-195,0080,0090,0.0000E+00,7.1534E-03,0.0000E+00  
 -196,0081,0082,0.0000E+00,5.7241E-03,0.0000E+00  
 -197,0081,0083,0.0000E+00,5.7241E-03,0.0000E+00  
 -198,0081,0084,0.0000E+00,5.7241E-03,0.0000E+00  
 -199,0081,0085,0.0000E+00,5.7241E-03,0.0000E+00  
 -200,0081,0087,0.0000E+00,5.7241E-03,0.0000E+00  
 -201,0081,0087,0.0000E+00,5.7241E-03,0.0000E+00  
 -202,0081,0088,0.0000E+00,5.7241E-03,0.0000E+00  
 -203,0081,0089,0.0000E+00,5.7241E-03,0.0000E+00  
 -204,0081,0090,0.0000E+00,5.7241E-03,0.0000E+00  
 -205,0082,0083,1.7647E-01,6.6005E-03,1.3864E-01  
 -206,0082,0084,1.7647E-01,6.6005E-03,1.3184E-01  
 -207,0082,0085,1.7647E-01,6.6005E-03,4.2420E-02  
 -208,0082,0087,1.7647E-01,6.6005E-03,2.7920E-02  
 -209,0082,0087,1.7647E-01,6.6005E-03,1.8730E-02  
 -210,0082,0088,1.7647E-01,6.6005E-03,3.1190E-02  
 -211,0082,0089,1.7647E-01,6.6005E-03,1.8460E-02  
 -212,0082,0090,1.7647E-01,6.6005E-03,1.1160E-02  
 -213,0083,0084,1.7647E-01,7.1313E-03,1.9293E-01  
 -214,0083,0085,1.7647E-01,7.1313E-03,6.3220E-02  
 -215,0083,0087,1.7647E-01,7.1313E-03,4.3630E-02  
 -216,0083,0087,1.7647E-01,7.1313E-03,2.3120E-02  
 -217,0083,0088,1.7647E-01,7.1313E-03,4.6880E-02  
 -218,0083,0089,1.7647E-01,7.1313E-03,2.8120E-02  
 -219,0083,0090,1.7647E-01,7.1313E-03,1.6860E-02  
 -220,0084,0085,1.7647E-01,7.4924E-03,7.4079E-02  
 -221,0084,0087,1.7647E-01,7.4924E-03,4.8855E-02  
 -222,0084,0087,1.7647E-01,7.4924E-03,1.4130E-02  
 -223,0084,0088,1.7647E-01,7.4924E-03,3.0524E-02  
 -224,0084,0089,1.7647E-01,7.4924E-03,2.3974E-02  
 -225,0084,0090,1.7647E-01,7.4924E-03,1.5333E-02  
 -226,0085,0087,1.7647E-01,4.1542E-03,1.1240E-01  
 -227,0085,0087,1.7647E-01,4.1542E-03,5.7223E-02  
 -228,0085,0088,1.7647E-01,4.1542E-03,1.2172E-01  
 -229,0085,0089,1.7647E-01,4.1542E-03,6.2873E-02  
 -230,0085,0090,1.7647E-01,4.1542E-03,3.2738E-02  
 -231,0087,0087,0.0000E+00,3.9867E-03,0.0000E+00  
 -232,0087,0088,1.7647E-01,3.9867E-03,1.4584E-01  
 -233,0087,0089,1.7647E-01,3.9867E-03,4.0970E-02  
 -234,0087,0090,1.7647E-01,3.9867E-03,1.7390E-02

COMM

COMMConduction paths for inside the convenience jar wall

COMM C#, N1, N2, K or H , AREA , DX or DR

COMM (m<sup>2</sup>) , (m)

0235,0071,0072,1.3650E+01,3.1416E-05,5.7565E-03  
 0236,0072,0073,1.3650E+01,9.4248E-05,9.1783E-03  
 0237,0073,0074,1.3650E+01,1.5708E-04,1.0890E-02  
 0238,0074,0075,1.3650E+01,2.3562E-04,1.4626E-02  
 0239,0075,0076,1.3650E+01,3.1770E-04,1.4637E-02  
 0240,0076,0077,1.3650E+01,3.4872E-04,1.7919E-02  
 0241,0077,0078,1.3650E+01,3.4872E-04,1.0350E-02  
 0242,0078,0079,1.3650E+01,3.4872E-04,1.0350E-02  
 0243,0079,0080,1.3650E+01,3.4872E-04,1.0350E-02  
 0244,0080,0081,1.3650E+01,3.4872E-04,1.0350E-02  
 0245,0081,0082,1.3650E+01,3.4872E-04,8.2820E-03  
 0246,0082,0083,1.3650E+01,3.4872E-04,9.5500E-03  
 0247,0083,0084,1.3650E+01,3.4872E-04,1.0318E-02  
 0248,0084,0085,1.3650E+01,2.9395E-03,1.0350E-02

0249,0085,0086,1.3650E+01,1.2260E-03,7.0500E-03  
 0250,0085,0087,1.3650E+01,2.2643E-03,1.0050E-02  
 0251,0086,0087,1.3650E+01,6.6177E-03,9.1245E-03  
 0252,0087,0088,1.3650E+01,1.4137E-03,1.4626E-02  
 0253,0088,0089,1.3650E+01,9.4248E-04,1.0890E-02  
 0254,0089,0090,1.3650E+01,5.6549E-04,9.1783E-03  
 0255,0090,0091,1.3650E+01,1.8850E-04,5.7565E-03

COMM

COMM Contact resistance paths between the bottom of the convenience jar and ...

COMM C#, N1, N2,H , AREA , DR or 1  
 COMM (m<sup>2</sup>) , (m or -)

0256,0110,0071,1.8928E+03,7.8540E-05,1.0000E+00  
 0257,0111,0072,1.8928E+03,6.2832E-04,1.0000E+00  
 0258,0112,0073,1.8928E+03,1.2566E-03,1.0000E+00  
 0259,0113,0074,1.8928E+03,2.4544E-03,1.0000E+00

COMM

COMM Conduction paths for inside the gas space between the convenience jar ...

COMM C#, N1, N2, K or H , AREA , DX or DR  
 COMM (m<sup>2</sup>) , (m)

0260,0092,0093,2.5810E-02,1.4179E-04,1.5173E-02  
 0261,0093,0094,2.5810E-02,3.5500E-04,1.8061E-02  
 0262,0094,0095,2.5810E-02,3.5500E-04,2.0700E-02  
 0263,0095,0096,2.5810E-02,3.5500E-04,2.0700E-02  
 0264,0096,0097,2.5810E-02,3.5500E-04,2.0700E-02  
 0265,0097,0098,2.5810E-02,3.5500E-04,1.8632E-02  
 0266,0098,0099,2.5810E-02,3.5500E-04,1.7832E-02  
 0267,0099,0100,2.5810E-02,3.5500E-04,1.9868E-02  
 0268,0100,0101,2.5810E-02,3.5500E-04,2.0668E-02  
 0269,0101,0102,2.5810E-02,3.5500E-04,1.7400E-02  
 0270,0102,0103,2.5810E-02,3.5500E-04,1.7100E-02  
 0271,0103,0104,2.5810E-02,3.5500E-04,1.3550E-02  
 0272,0104,0105,1.2905E-01,2.3047E-03,9.1245E-03  
 0273,0105,0106,1.2905E-01,1.6493E-03,1.4626E-02  
 0274,0106,0107,1.2905E-01,1.0996E-03,1.0890E-02  
 0275,0107,0108,1.2905E-01,6.5973E-04,9.1783E-03  
 0276,0108,0109,1.2905E-01,2.1991E-04,5.7565E-03

COMM

COMM Conduction paths from convenience jar to gas outside

COMM C#, N1, N2, K or H , AREA , DX or DR  
 COMM (m<sup>2</sup>) , (m)

0277,0075,0092,2.5810E-02,4.3652E-03,4.9997E-04  
 0278,0076,0093,2.5810E-02,4.9841E-03,4.9997E-04  
 0279,0077,0094,2.5810E-02,7.2835E-03,4.9997E-04  
 0280,0078,0095,2.5810E-02,7.2835E-03,4.9997E-04  
 0281,0079,0096,2.5810E-02,7.2835E-03,4.9997E-04  
 0282,0080,0097,2.5810E-02,7.2835E-03,4.9997E-04  
 0283,0081,0098,2.5810E-02,5.8282E-03,4.9997E-04  
 0284,0082,0099,2.5810E-02,6.7205E-03,4.9997E-04  
 0285,0083,0100,2.5810E-02,7.2609E-03,4.9997E-04  
 0286,0084,0101,2.5810E-02,7.2835E-03,4.9997E-04  
 0287,0085,0102,2.5810E-02,4.9612E-03,4.9997E-04  
 0288,0086,0103,2.5810E-02,7.0724E-03,4.9997E-04  
 0289,0086,0104,2.5810E-02,1.5810E-03,3.5000E-03  
 0290,0087,0105,2.5810E-02,4.2082E-03,3.5000E-03  
 0291,0088,0106,2.5810E-02,2.4544E-03,3.5000E-03  
 0292,0089,0107,2.5810E-02,1.2566E-03,3.5000E-03  
 0293,0090,0108,2.5810E-02,6.2832E-04,3.5000E-03  
 0294,0091,0109,2.5810E-02,7.8540E-05,3.5000E-03

COMM

COMM Conduction paths from gas inside inner container to inner container

COMM C#, N1, N2, K or H , AREA , DX or DR

COMM (m<sup>2</sup>) , (m)

0295,0092,0114,2.5810E-02,4.4951E-03,4.9997E-04  
 0296,0093,0115,2.5810E-02,5.1112E-03,4.9997E-04  
 0297,0094,0116,2.5810E-02,7.4135E-03,4.9997E-04  
 0298,0095,0117,2.5810E-02,7.4135E-03,4.9997E-04  
 0299,0096,0118,2.5810E-02,7.4135E-03,4.9997E-04  
 0300,0097,0119,2.5810E-02,7.4135E-03,4.9997E-04  
 0301,0098,0120,2.5810E-02,5.9323E-03,4.9997E-04  
 0302,0099,0121,2.5810E-02,6.8405E-03,4.9997E-04  
 0303,0100,0122,2.5810E-02,7.3906E-03,4.9997E-04  
 0304,0101,0123,2.5810E-02,7.4135E-03,4.9997E-04  
 0305,0102,0124,2.5810E-02,5.0498E-03,4.9997E-04  
 0306,0103,0125,2.5810E-02,7.1986E-03,4.9997E-04  
 0307,0104,0126,2.5810E-02,2.5070E-03,4.9997E-04  
 0308,0104,0127,2.5810E-02,1.5810E-03,3.5000E-03  
 0309,0105,0128,2.5810E-02,4.2082E-03,3.5000E-03  
 0310,0106,0129,2.5810E-02,2.4544E-03,3.5000E-03  
 0311,0107,0130,2.5810E-02,1.2566E-03,3.5000E-03  
 0312,0108,0131,2.5810E-02,6.2832E-04,3.5000E-03  
 0313,0109,0132,2.5810E-02,7.8540E-05,3.5000E-03

COMM

COMM Radiation paths between the convenience container and the inner container

COMM C#, N1, N2,Emissivity, AREA ,VIEW FACT

COMM (m<sup>2</sup>) , (-)

-314,0075,0114,1.7647E-01,4.3652E-03,1.0000E+00  
 -315,0076,0115,1.7647E-01,4.9841E-03,1.0000E+00  
 -316,0077,0116,1.7647E-01,7.2835E-03,1.0000E+00  
 -317,0078,0117,1.7647E-01,7.2835E-03,1.0000E+00  
 -318,0079,0118,1.7647E-01,7.2835E-03,1.0000E+00  
 -319,0080,0119,1.7647E-01,7.2835E-03,1.0000E+00  
 -320,0081,0120,1.7647E-01,5.8282E-03,1.0000E+00  
 -321,0082,0121,1.7647E-01,6.7205E-03,1.0000E+00  
 -322,0083,0122,1.7647E-01,7.2609E-03,1.0000E+00  
 -323,0084,0123,1.7647E-01,7.2835E-03,1.0000E+00  
 -324,0085,0124,1.7647E-01,4.9612E-03,1.0000E+00  
 -325,0086,0125,1.7647E-01,7.0724E-03,1.0000E+00  
 -326,0091,0126,1.7647E-01,7.8540E-05,1.4950E-02  
 -327,0091,0127,1.7647E-01,7.8540E-05,2.7200E-03  
 -328,0091,0128,1.7647E-01,7.8540E-05,1.6520E-02  
 -329,0091,0129,1.7647E-01,7.8540E-05,4.0930E-02  
 -330,0091,0130,1.7647E-01,7.8540E-05,1.1725E-01  
 -331,0091,0131,1.7647E-01,7.8540E-05,5.3470E-01  
 -332,0091,0132,1.7647E-01,7.8540E-05,2.7293E-01  
 -333,0090,0126,1.7647E-01,6.2832E-04,1.6040E-02  
 -334,0090,0127,1.7647E-01,6.2832E-04,3.1600E-03  
 -335,0090,0128,1.7647E-01,6.2832E-04,2.0980E-02  
 -336,0090,0129,1.7647E-01,6.2832E-04,6.6910E-02  
 -337,0090,0130,1.7647E-01,6.2832E-04,2.8452E-01  
 -338,0090,0131,1.7647E-01,6.2832E-04,5.4150E-01  
 -339,0090,0132,1.7647E-01,6.2832E-04,6.6890E-02  
 -340,0089,0126,1.7647E-01,1.2566E-03,1.9560E-02  
 -341,0089,0127,1.7647E-01,1.2566E-03,4.7800E-03  
 -342,0089,0128,1.7647E-01,1.2566E-03,4.1780E-02  
 -343,0089,0129,1.7647E-01,1.2566E-03,2.5539E-01  
 -344,0089,0130,1.7647E-01,1.2566E-03,5.2887E-01

-345,0089,0131,1.7647E-01,1.2566E-03,1.4229E-01  
 -346,0089,0132,1.7647E-01,1.2566E-03,7.3300E-03  
 -347,0088,0126,1.7647E-01,2.4544E-03,3.1160E-02  
 -348,0088,0127,1.7647E-01,2.4544E-03,1.2270E-02  
 -349,0088,0128,1.7647E-01,2.4544E-03,2.1685E-01  
 -350,0088,0129,1.7647E-01,2.4544E-03,5.9053E-01  
 -351,0088,0130,1.7647E-01,2.4544E-03,1.3075E-01  
 -352,0088,0131,1.7647E-01,2.4544E-03,1.7130E-02  
 -353,0088,0132,1.7647E-01,2.4544E-03,1.3100E-03  
 -354,0087,0126,1.7647E-01,4.2082E-03,1.1003E-01  
 -355,0087,0127,1.7647E-01,4.2082E-03,1.1021E-01  
 -356,0087,0128,1.7647E-01,4.2082E-03,6.3741E-01  
 -357,0087,0129,1.7647E-01,4.2082E-03,1.2643E-01  
 -358,0087,0130,1.7647E-01,4.2082E-03,1.2470E-02  
 -359,0087,0131,1.7647E-01,4.2082E-03,3.1300E-03  
 -360,0087,0132,1.7647E-01,4.2082E-03,3.2000E-04  
 -361,0086,0126,1.7647E-01,1.2260E-03,3.4998E-01  
 -362,0086,0127,1.7647E-01,1.2260E-03,3.0461E-01  
 -363,0086,0128,1.7647E-01,1.2260E-03,3.1977E-01  
 -364,0086,0129,1.7647E-01,1.2260E-03,2.0230E-02  
 -365,0086,0130,1.7647E-01,1.2260E-03,3.9700E-03  
 -366,0086,0131,1.7647E-01,1.2260E-03,1.3000E-03  
 -367,0086,0132,1.7647E-01,1.2260E-03,1.4000E-04  
 -368,0126,0127,1.7647E-01,2.5070E-03,2.4998E-01  
 -369,0126,0128,1.7647E-01,2.5070E-03,1.7813E-01  
 -370,0126,0129,1.7647E-01,2.5070E-03,2.9410E-02  
 -371,0126,0130,1.7647E-01,2.5070E-03,9.4500E-03  
 -372,0126,0131,1.7647E-01,2.5070E-03,3.8800E-03  
 -373,0126,0132,1.7647E-01,2.5070E-03,4.5000E-04

COMM

COMM Conduction paths for inside the inner container wall

COMM C#, N1, N2, K or H , AREA , DX or DR

COMM (m^2) , (m)

0374,0133,0110,1.3650E+01,7.8540E-05,7.5000E-04  
 0375,0134,0111,1.3650E+01,6.2832E-04,7.5000E-04  
 0376,0135,0112,1.3650E+01,1.2566E-03,7.5000E-04  
 0377,0136,0113,1.3650E+01,2.4544E-03,7.5000E-04  
 0378,0110,0111,1.3650E+01,4.7124E-05,5.7565E-03  
 0379,0111,0112,1.3650E+01,1.4137E-04,9.1783E-03  
 0380,0112,0113,1.3650E+01,2.3562E-04,1.0890E-02  
 0381,0113,0114,1.3650E+01,3.5343E-04,1.3405E-02  
 0382,0114,0115,1.3650E+01,4.9660E-04,1.0370E-02  
 0383,0115,0116,1.3650E+01,5.4428E-04,1.8302E-02  
 0384,0116,0117,1.3650E+01,5.4428E-04,2.0700E-02  
 0385,0117,0118,1.3650E+01,5.4428E-04,2.0700E-02  
 0386,0118,0119,1.3650E+01,5.4428E-04,2.0700E-02  
 0387,0119,0120,1.3650E+01,5.4428E-04,1.8632E-02  
 0388,0120,0121,1.3650E+01,5.4428E-04,1.7832E-02  
 0389,0121,0122,1.3650E+01,5.4428E-04,1.9868E-02  
 0390,0122,0123,1.3650E+01,5.4428E-04,2.0668E-02  
 0391,0123,0124,1.3650E+01,5.4428E-04,1.7400E-02  
 0392,0124,0125,1.3650E+01,5.4428E-04,1.7100E-02  
 0393,0125,0126,1.3650E+01,5.4428E-04,1.3550E-02  
 0394,0126,0127,1.3650E+01,5.4428E-04,8.0000E-03  
 0395,0127,0128,1.3650E+01,4.9386E-04,1.0370E-02  
 0396,0128,0129,1.3650E+01,3.5343E-04,1.3405E-02  
 0397,0129,0130,1.3650E+01,2.3562E-04,1.0890E-02  
 0398,0130,0131,1.3650E+01,1.4137E-04,9.1783E-03

0399,0131,0132,1.3650E+01,4.7124E-05,5.7565E-03  
 COMM  
 COMM Contact resistance paths between the bottom of the inner container and ...  
 COMM C#, N1, N2, H , AREA , DR or 1  
 COMM (m^2) , (m or -)  
 0400,0157,0133,1.8928E+03,7.8540E-05,1.0000E+00  
 0401,0158,0134,1.8928E+03,6.2832E-04,1.0000E+00  
 0402,0159,0135,1.8928E+03,1.2566E-03,1.0000E+00  
 0403,0160,0136,1.8928E+03,2.4544E-03,1.0000E+00  
 COMM  
 COMM Conduction paths for inside the gas space between the inner and outer ...  
 COMM C#, N1, N2, K or H , AREA , DX or DR  
 COMM (m^2) , (m)  
 0404,0137,0138,2.5810E-02,2.0418E-03,1.0370E-02  
 0405,0138,0139,2.5810E-02,3.7071E-04,1.8561E-02  
 0406,0139,0140,2.5810E-02,3.7071E-04,2.0700E-02  
 0407,0140,0141,2.5810E-02,3.7071E-04,2.0700E-02  
 0408,0141,0142,2.5810E-02,3.7071E-04,2.0700E-02  
 0409,0142,0143,2.5810E-02,3.7071E-04,1.8632E-02  
 0410,0143,0144,2.5810E-02,3.7071E-04,1.7832E-02  
 0411,0144,0145,2.5810E-02,3.7071E-04,1.9868E-02  
 0412,0145,0146,2.5810E-02,3.7071E-04,2.0668E-02  
 0413,0146,0147,2.5810E-02,3.7071E-04,1.7400E-02  
 0414,0147,0148,2.5810E-02,3.7071E-04,1.7100E-02  
 0415,0148,0149,2.5810E-02,3.7071E-04,1.3550E-02  
 0416,0149,0150,2.5810E-02,3.7071E-04,8.0000E-03  
 0417,0150,0151,2.5810E-02,3.7071E-04,6.5000E-03  
 0418,0151,0152,1.2905E-01,3.7862E-03,1.0370E-02  
 0419,0152,0153,1.2905E-01,2.7096E-03,1.3405E-02  
 0420,0153,0154,1.2905E-01,1.8064E-03,1.0890E-02  
 0421,0154,0155,1.2905E-01,1.0838E-03,9.1783E-03  
 0422,0155,0156,1.2905E-01,3.6128E-04,5.7565E-03  
 COMM  
 COMM Conduction paths from the inner container to gas outside  
 COMM C#, N1, N2, K or H , AREA , DX or DR  
 COMM (m^2) , (m)  
 0423,0114,0137,2.5810E-02,4.7214E-03,9.3237E-04  
 0424,0115,0138,2.5810E-02,5.8218E-03,2.4915E-03  
 0425,0116,0139,2.5810E-02,7.6086E-03,4.9998E-04  
 0426,0117,0140,2.5810E-02,7.6086E-03,4.9998E-04  
 0427,0118,0141,2.5810E-02,7.6086E-03,4.9998E-04  
 0428,0119,0142,2.5810E-02,7.6086E-03,4.9998E-04  
 0429,0120,0143,2.5810E-02,6.0884E-03,4.9998E-04  
 0430,0121,0144,2.5810E-02,7.0205E-03,4.9998E-04  
 0431,0122,0145,2.5810E-02,7.5851E-03,4.9998E-04  
 0432,0123,0146,2.5810E-02,7.6086E-03,4.9998E-04  
 0433,0124,0147,2.5810E-02,5.1827E-03,4.9998E-04  
 0434,0125,0148,2.5810E-02,7.3881E-03,4.9998E-04  
 0435,0126,0149,2.5810E-02,2.5730E-03,4.9998E-04  
 0436,0127,0150,2.5810E-02,3.3081E-03,4.9998E-04  
 0437,0127,0151,2.5810E-02,4.7406E-03,1.8843E-03  
 0438,0128,0152,2.5810E-02,4.2082E-03,5.7500E-03  
 0439,0129,0153,2.5810E-02,2.4544E-03,5.7500E-03  
 0440,0130,0154,2.5810E-02,1.2566E-03,5.7500E-03  
 0441,0131,0155,2.5810E-02,6.2832E-04,5.7500E-03  
 0442,0132,0156,2.5810E-02,7.8540E-05,5.7500E-03  
 COMM  
 COMM Conduction paths from gas inside outer container to outer container

COMM C#, N1, N2, K or H , AREA , DX or DR  
 COMM (m<sup>2</sup>) , (m)  
 0443,0137,0165,2.5810E-02,4.2082E-03,1.0461E-03  
 0444,0138,0172,2.5810E-02,2.0960E-03,6.9202E-03  
 0445,0138,0173,2.5810E-02,7.4374E-03,1.9074E-03  
 0446,0139,0174,2.5810E-02,7.7387E-03,4.9998E-04  
 0447,0140,0174,2.5810E-02,7.7387E-03,4.9998E-04  
 0448,0141,0175,2.5810E-02,7.7387E-03,4.9998E-04  
 0449,0142,0175,2.5810E-02,7.7387E-03,4.9998E-04  
 0450,0143,0176,2.5810E-02,6.1924E-03,4.9998E-04  
 0451,0144,0177,2.5810E-02,7.1825E-03,4.9998E-04  
 0452,0145,0178,2.5810E-02,7.7148E-03,4.9998E-04  
 0453,0146,0178,2.5810E-02,7.7387E-03,4.9998E-04  
 0454,0147,0179,2.5810E-02,5.2713E-03,4.9998E-04  
 0455,0148,0179,2.5810E-02,7.5144E-03,4.9998E-04  
 0456,0149,0179,2.5810E-02,2.6169E-03,4.9998E-04  
 0457,0150,0180,2.5810E-02,3.3646E-03,4.9998E-04  
 0458,0151,0180,2.5810E-02,1.4954E-03,3.5408E-03  
 0459,0151,0181,2.5810E-02,2.4960E-03,3.5788E-03  
 0460,0152,0182,2.5810E-02,4.2082E-03,5.7500E-03  
 0461,0153,0183,2.5810E-02,2.4544E-03,5.7500E-03  
 0462,0154,0184,2.5810E-02,1.2566E-03,5.7500E-03  
 0463,0155,0185,2.5810E-02,6.2832E-04,5.7500E-03  
 0464,0156,0186,2.5810E-02,7.8540E-05,5.7500E-03  
 COMM  
 COMM Radiation paths between the inner and outer containers  
 COMM C#, N1, N2, Emissivity, AREA ,VIEW FACT  
 COMM (m<sup>2</sup>) , (-)  
 -465,0114,0165,1.7647E-01,4.7214E-03,1.0000E+00  
 -466,0115,0173,1.7647E-01,5.8218E-03,1.0000E+00  
 -467,0116,0174,1.7647E-01,7.6086E-03,1.0000E+00  
 -468,0117,0174,1.7647E-01,7.6086E-03,1.0000E+00  
 -469,0118,0175,1.7647E-01,7.6086E-03,1.0000E+00  
 -470,0119,0175,1.7647E-01,7.6086E-03,1.0000E+00  
 -471,0120,0176,1.7647E-01,6.0884E-03,1.0000E+00  
 -472,0121,0177,1.7647E-01,7.0205E-03,1.0000E+00  
 -473,0122,0178,1.7647E-01,7.5851E-03,1.0000E+00  
 -474,0123,0178,1.7647E-01,7.6086E-03,1.0000E+00  
 -475,0124,0179,1.7647E-01,5.1827E-03,1.0000E+00  
 -476,0125,0179,1.7647E-01,7.3881E-03,1.0000E+00  
 -477,0126,0179,1.7647E-01,2.5730E-03,1.0000E+00  
 -478,0127,0180,1.7647E-01,3.3081E-03,1.0000E+00  
 -479,0132,0127,1.7647E-01,7.8540E-05,1.8050E-02  
 -480,0132,0180,1.7647E-01,7.8540E-05,2.2210E-02  
 -481,0132,0181,1.7647E-01,7.8540E-05,6.9300E-03  
 -482,0132,0182,1.7647E-01,7.8540E-05,4.0830E-02  
 -483,0132,0183,1.7647E-01,7.8540E-05,9.2010E-02  
 -484,0132,0184,1.7647E-01,7.8540E-05,2.0665E-01  
 -485,0132,0185,1.7647E-01,7.8540E-05,4.7301E-01  
 -486,0132,0186,1.7647E-01,7.8540E-05,1.4031E-01  
 -487,0131,0127,1.7647E-01,6.2832E-04,1.9420E-02  
 -488,0131,0180,1.7647E-01,6.2832E-04,2.3670E-02  
 -489,0131,0181,1.7647E-01,6.2832E-04,7.9600E-03  
 -490,0131,0182,1.7647E-01,6.2832E-04,5.0320E-02  
 -491,0131,0183,1.7647E-01,6.2832E-04,1.3181E-01  
 -492,0131,0184,1.7647E-01,6.2832E-04,3.1154E-01  
 -493,0131,0185,1.7647E-01,6.2832E-04,3.9613E-01  
 -494,0131,0186,1.7647E-01,6.2832E-04,5.9150E-02

-495,0130,0127,1.7647E-01,1.2566E-03,2.3910E-02  
 -496,0130,0180,1.7647E-01,1.2566E-03,2.8250E-02  
 -497,0130,0181,1.7647E-01,1.2566E-03,1.1650E-02  
 -498,0130,0182,1.7647E-01,1.2566E-03,8.9090E-02  
 -499,0130,0183,1.7647E-01,1.2566E-03,2.9233E-01  
 -500,0130,0184,1.7647E-01,1.2566E-03,3.8614E-01  
 -501,0130,0185,1.7647E-01,1.2566E-03,1.5572E-01  
 -502,0130,0186,1.7647E-01,1.2566E-03,1.2910E-02  
 -503,0129,0127,1.7647E-01,2.4544E-03,3.9180E-02  
 -504,0129,0180,1.7647E-01,2.4544E-03,3.9320E-02  
 -505,0129,0181,1.7647E-01,2.4544E-03,2.6240E-02  
 -506,0129,0182,1.7647E-01,2.4544E-03,2.6346E-01  
 -507,0129,0183,1.7647E-01,2.4544E-03,4.4540E-01  
 -508,0129,0184,1.7647E-01,2.4544E-03,1.4971E-01  
 -509,0129,0185,1.7647E-01,2.4544E-03,3.6690E-02  
 -510,0128,0127,1.7647E-01,4.2082E-03,1.4882E-01  
 -511,0128,0180,1.7647E-01,4.2082E-03,5.5580E-02  
 -512,0128,0181,1.7647E-01,4.2082E-03,1.1159E-01  
 -513,0128,0182,1.7647E-01,4.2082E-03,4.9531E-01  
 -514,0128,0183,1.7647E-01,4.2082E-03,1.5378E-01  
 -515,0128,0184,1.7647E-01,4.2082E-03,3.4920E-02  
 -516,0127,0127,1.7647E-01,1.0508E-03,4.3510E-01  
 -517,0127,0180,1.7647E-01,1.0508E-03,1.0350E-02  
 -518,0127,0181,1.7647E-01,1.0508E-03,1.7494E-01  
 -519,0127,0182,1.7647E-01,1.0508E-03,3.2188E-01  
 -520,0127,0183,1.7647E-01,1.0508E-03,4.4180E-02  
 -521,0127,0184,1.7647E-01,1.0508E-03,1.3550E-02  
 -522,0127,0180,1.7647E-01,2.6154E-03,2.0720E-02  
 -523,0127,0181,1.7647E-01,2.6154E-03,4.8040E-02  
 -524,0127,0182,1.7647E-01,2.6154E-03,2.1840E-01  
 -525,0127,0183,1.7647E-01,2.6154E-03,5.4060E-02  
 -526,0127,0184,1.7647E-01,2.6154E-03,1.8370E-02  
 -527,0127,0185,1.7647E-01,2.6154E-03,8.4400E-03  
 -528,0127,0180,1.7647E-01,1.0744E-03,3.1006E-01  
 -529,0127,0181,1.7647E-01,1.0744E-03,5.8899E-01  
 -530,0127,0182,1.7647E-01,1.0744E-03,1.0095E-01  
 -531,0180,0181,1.7647E-01,1.4954E-03,3.7720E-01  
 -532,0180,0182,1.7647E-01,1.4954E-03,8.5330E-02  
 -533,0180,0183,1.7647E-01,1.4954E-03,2.1880E-02

COMM

COMM Conduction paths for inside the outer container wall

COMM C#, N1, N2, K or H , AREA , DX or DR

COMM (m<sup>2</sup>) , (m)

0534,0166,0161,1.3650E+01,7.8540E-05,4.5000E-03  
 0535,0167,0162,1.3650E+01,6.2832E-04,4.5000E-03  
 0536,0168,0163,1.3650E+01,1.2566E-03,4.5000E-03  
 0537,0169,0164,1.3650E+01,2.4544E-03,4.5000E-03  
 0538,0170,0165,1.3650E+01,4.2082E-03,4.5000E-03  
 0539,0171,0172,1.3650E+01,3.6458E-03,4.5000E-03  
 0540,0161,0157,1.3650E+01,7.8540E-05,4.5000E-03  
 0541,0162,0158,1.3650E+01,6.2832E-04,4.5000E-03  
 0542,0163,0159,1.3650E+01,1.2566E-03,4.5000E-03  
 0543,0164,0160,1.3650E+01,2.4544E-03,4.5000E-03  
 0544,0161,0162,1.3650E+01,1.4137E-04,5.7565E-03  
 0545,0162,0163,1.3650E+01,4.2412E-04,9.1783E-03  
 0546,0163,0164,1.3650E+01,7.0686E-04,1.0890E-02  
 0547,0164,0165,1.3650E+01,1.0603E-03,1.3405E-02  
 0548,0165,0172,1.3650E+01,1.4816E-03,1.2349E-02

0549,0172,0173,1.3650E+01,1.3373E-03,1.5000E-02  
 0550,0173,0174,1.3650E+01,1.1498E-03,3.1200E-02  
 0551,0174,0175,1.3650E+01,1.1498E-03,4.1400E-02  
 0552,0175,0176,1.3650E+01,1.1498E-03,2.8982E-02  
 0553,0176,0177,1.3650E+01,1.1498E-03,1.7832E-02  
 0554,0177,0178,1.3650E+01,1.1498E-03,3.0218E-02  
 0555,0178,0179,1.3650E+01,1.1498E-03,4.1268E-02  
 0556,0179,0180,1.3650E+01,1.1498E-03,2.7100E-02  
 0557,0180,0181,1.3650E+01,1.1498E-03,1.1500E-02  
 0558,0181,0182,1.3650E+01,3.2924E-03,1.2349E-02  
 0559,0182,0183,1.3650E+01,2.3562E-03,1.3405E-02  
 0560,0183,0184,1.3650E+01,1.5708E-03,1.0890E-02  
 0561,0184,0185,1.3650E+01,9.4248E-04,9.1783E-03  
 0562,0185,0186,1.3650E+01,3.1416E-04,5.7565E-03

COMM

COMM Heat transfer paths due to support plate for the container

COMM C#, N1, N2, K or H , AREA , DX or DR  
COMM (m<sup>2</sup>) , (m)

0563,0166,0187,1.3650E+01,7.8540E-05,2.3812E-03  
 0564,0167,0187,1.3650E+01,6.2832E-04,2.3812E-03  
 0565,0168,0187,1.3650E+01,1.2566E-03,2.3812E-03  
 0566,0169,0188,1.3650E+01,2.4544E-03,2.3812E-03  
 0567,0170,0188,1.3650E+01,4.2082E-03,2.3812E-03  
 0568,0171,0188,1.3650E+01,3.6458E-03,2.3812E-03  
 0569,0187,0188,1.3650E+01,7.4809E-04,2.4762E-02  
 0570,0188,0189,1.3650E+01,1.8702E-03,3.5042E-02  
 0571,0189,0190,1.3650E+01,2.9924E-03,4.7000E-02  
 0572,0190,0191,1.3650E+01,4.7878E-03,6.7619E-02

COMM

COMM Convection and Radiation Conductors to boundary temperature nodes

COMM C#, N1, N2, K or H , AREA , DX or DR  
COMM epsilon , (m<sup>2</sup>) , or V.F.

0573,0187,0192,1.4700E+00,1.9635E-03,1.0000E+00  
 0574,0188,0192,1.4700E+00,1.0308E-02,1.0000E+00  
 0575,0189,0192,1.4700E+00,1.9144E-02,1.0000E+00  
 0576,0190,0192,1.4700E+00,4.9009E-02,1.0000E+00  
 0577,0191,0192,1.4700E+00,9.9575E-02,1.0000E+00  
 0578,0191,0192,2.2000E+00,7.1627E-03,1.0000E+00  
 0579,0191,0192,2.4700E+00,9.9575E-02,1.0000E+00  
 0580,0190,0192,2.4700E+00,4.9009E-02,1.0000E+00  
 0581,0189,0192,2.4700E+00,1.9144E-02,1.0000E+00  
 0582,0172,0192,2.2000E+00,3.5343E-03,1.0000E+00  
 0583,0173,0192,2.2000E+00,8.2467E-03,1.0000E+00  
 0584,0174,0192,2.2000E+00,1.6258E-02,1.0000E+00  
 0585,0175,0192,2.2000E+00,1.6258E-02,1.0000E+00  
 0586,0176,0192,2.2000E+00,6.5047E-03,1.0000E+00  
 0587,0177,0192,2.2000E+00,7.5006E-03,1.0000E+00  
 0588,0178,0192,2.2000E+00,1.6233E-02,1.0000E+00  
 0589,0179,0192,2.2000E+00,1.6179E-02,1.0000E+00  
 0590,0180,0192,2.2000E+00,5.1051E-03,1.0000E+00  
 0591,0181,0192,2.2000E+00,3.9270E-03,1.0000E+00  
 0592,0181,0192,2.4700E+00,3.6458E-03,1.0000E+00  
 0593,0182,0192,2.4700E+00,4.2082E-03,1.0000E+00  
 0594,0183,0192,2.4700E+00,2.4544E-03,1.0000E+00  
 0595,0184,0192,2.4700E+00,1.2566E-03,1.0000E+00  
 0596,0185,0192,2.4700E+00,6.2832E-04,1.0000E+00  
 0597,0186,0192,2.4700E+00,7.8540E-05,1.0000E+00  
 -598,0187,0192,1.7647E-01,1.9635E-03,1.0000E+00

-599,0188,0192,1.7647E-01,1.0308E-02,1.0000E+00  
 -600,0189,0192,1.7647E-01,1.9144E-02,1.0000E+00  
 -601,0190,0192,1.7647E-01,4.9009E-02,1.0000E+00  
 -602,0191,0192,1.7647E-01,9.9575E-02,1.0000E+00  
 -603,0191,0192,1.7647E-01,7.1627E-03,1.0000E+00  
 -604,0191,0192,1.7647E-01,9.9575E-02,9.2416E-01  
 -605,0190,0192,1.7647E-01,4.9009E-02,8.5329E-01  
 -606,0189,0192,1.7647E-01,1.9144E-02,7.1667E-01  
 -607,0172,0189,1.7647E-01,3.5343E-03,4.3346E-01  
 -608,0172,0190,1.7647E-01,3.5343E-03,3.8920E-02  
 -609,0172,0191,1.7647E-01,3.5343E-03,1.1690E-02  
 -610,0172,0192,1.7647E-01,3.5343E-03,5.1593E-01  
 -611,0173,0189,1.7647E-01,8.2467E-03,2.5244E-01  
 -612,0173,0190,1.7647E-01,8.2467E-03,1.3407E-01  
 -613,0173,0191,1.7647E-01,8.2467E-03,4.8090E-02  
 -614,0173,0192,1.7647E-01,8.2467E-03,5.6539E-01  
 -615,0174,0189,1.7647E-01,1.6258E-02,7.8630E-02  
 -616,0174,0190,1.7647E-01,1.6258E-02,1.5988E-01  
 -617,0174,0191,1.7647E-01,1.6258E-02,9.7930E-02  
 -618,0174,0192,1.7647E-01,1.6258E-02,6.6356E-01  
 -619,0175,0189,1.7647E-01,1.6258E-02,2.0080E-02  
 -620,0175,0190,1.7647E-01,1.6258E-02,9.8160E-02  
 -621,0175,0191,1.7647E-01,1.6258E-02,1.1136E-01  
 -622,0175,0192,1.7647E-01,1.6258E-02,7.7040E-01  
 -623,0176,0189,1.7647E-01,6.5047E-03,9.3400E-03  
 -624,0176,0190,1.7647E-01,6.5047E-03,6.3090E-02  
 -625,0176,0191,1.7647E-01,6.5047E-03,9.9880E-02  
 -626,0176,0192,1.7647E-01,6.5047E-03,8.2769E-01  
 -627,0177,0190,1.7647E-01,7.5006E-03,5.5210E-02  
 -628,0177,0191,1.7647E-01,7.5006E-03,8.9590E-02  
 -629,0177,0192,1.7647E-01,7.5006E-03,8.5521E-01  
 -630,0178,0190,1.7647E-01,1.6233E-02,3.6410E-02  
 -631,0178,0191,1.7647E-01,1.6233E-02,7.2370E-02  
 -632,0178,0192,1.7647E-01,1.6233E-02,8.9122E-01  
 -633,0179,0190,1.7647E-01,1.6179E-02,2.1540E-02  
 -634,0179,0191,1.7647E-01,1.6179E-02,5.2600E-02  
 -635,0179,0192,1.7647E-01,1.6179E-02,9.2585E-01  
 -636,0180,0190,1.7647E-01,5.1051E-03,1.5670E-02  
 -637,0180,0191,1.7647E-01,5.1051E-03,4.2340E-02  
 -638,0180,0192,1.7647E-01,5.1051E-03,9.4200E-01  
 -639,0181,0190,1.7647E-01,3.9270E-03,1.3910E-02  
 -640,0181,0191,1.7647E-01,3.9270E-03,3.8850E-02  
 -641,0181,0192,1.7647E-01,3.9270E-03,9.4725E-01  
 -642,0181,0192,1.7647E-01,3.6458E-03,1.0000E+00  
 -643,0182,0192,1.7647E-01,4.2082E-03,1.0000E+00  
 -644,0183,0192,1.7647E-01,2.4544E-03,1.0000E+00  
 -645,0184,0192,1.7647E-01,1.2566E-03,1.0000E+00  
 -646,0185,0192,1.7647E-01,6.2832E-04,1.0000E+00  
 -647,0186,0192,1.7647E-01,7.8540E-05,1.0000E+00

ENDD

CNTL DATA

TSTP=0.0  
 BETA,0.5,  
 DCNV,0.000001,  
 NLOP,0,  
 TEND,0.0,  
 IPRT,0,  
 ISTA,0,

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RLAX,1.0,
IPRO,2,
ENDD
VAB1 DATA
    DIMENSION AH(42),DLH(42),ICH(42),ISH(42),IGH(42),IDH(42)
    DIMENSION AA(25),DLA(25),ICA(25),ISA(25),IGA(25),IDA(25)

C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR
C          CONVECTION HEAT TRANSFER BETWEEN ALL SURFACES
C          INSIDE THE BNFL CONTAINERS AND THE AIR
    DATA AH/7.1534E-03,5.7241E-03,6.6005E-03,7.1313E-03,
1       7.4924E-03,4.1542E-03,3.9867E-03,1.9439E-03,
2       2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
3       7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
4       5.0855E-03,1.5810E-03,4.2082E-03,2.4544E-03,
5       1.2566E-03,6.2832E-04,7.8540E-05,1.5810E-03,
6       4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
7       7.8540E-05,4.7406E-03,4.2082E-03,2.4544E-03,
8       1.2566E-03,6.2832E-04,7.8540E-05,1.4954E-03,
9       2.4960E-03,4.2082E-03,2.4544E-03,1.2566E-03,
A       6.2832E-04,7.8540E-05/

C
C      DLH IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR
C          CONVECTION HEAT TRANSFER BETWEEN ALL SURFACES
C          INSIDE THE BNFL CONTAINERS AND THE AIR
C          (FULL HEIGHT OF VERTICAL SURFACES OR SQRT(FULL
C          AREA) FOR HORIZONTAL SURFACES; DEFINED FOR PATHS
C          LISTED IN ARRAY ICH)
    DATA DLH/7*1.2590E-01,5*7.9760E-02,5*9.7485E-02,
1       12*1.0103E-01,13*1.0546E-01/

C
C      ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN ALL SURFACES INSIDE THE
C          BNFL CONTAINERS AND THE AIR
    DATA ICH/124,125,126,127,128,129,130,075,074,073,
1       072,071,041,042,043,044,045,289,290,291,
2       292,293,294,308,309,310,311,312,313,437,
3       438,439,440,441,442,458,459,460,461,462,
4       463,464/

C
C      ISH IS THE SURFACE NODE NUMBER FOR CONVECTION HEAT
C          TRANSFER BETWEEN ALL SURFACES INSIDE THE BNFL
C          CONTAINERS AND THE AIR
    DATA ISH/080,081,082,083,084,085,087,087,088,089,
1       090,091,061,062,063,064,065,086,087,088,
2       089,090,091,127,128,129,130,131,132,127,
3       128,129,130,131,132,180,181,182,183,184,
4       185,186/

C
C      IGH IS THE AIR NODE NUMBER FOR CONVECTION HEAT
C          TRANSFER BETWEEN ALL SURFACES INSIDE THE BNFL
C          CONTAINERS AND THE AIR
C          (AIR NODES FROM THE PATHS IN ICH)
    DATA IGH/025,030,035,040,045,050,055,055,054,053,
1       052,051,031,032,033,034,035,104,105,106,
2       107,108,109,104,105,106,107,108,109,151,
3       152,153,154,155,156,151,151,152,153,154,
4       155,156/

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C
C IDH DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C HEAT TRANSFER BETWEEN ALL SURFACES INSIDE THE
C BNFL CONTAINERS AND THE AIR
C (FOR PATHS IN ICH)
C -1 = HORIZONTAL BOTTOM SURFACE (AIR BELOW SURFACE)
C 0 = VERTICAL SURFACE
C 1 = HORIZONTAL TOP SURFACE (AIR ABOVE SURFACE)
DATA IDH/7*0,5*-1,5*1,6*1,6*-1,6*1,0,6*-1/

C
C AA IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR
C CONVECTION HEAT TRANSFER BETWEEN THE PLATE AND
C BNFL OUTER-CONTAINER OUTER SURFACES AND THE AIR
DATA AA/1.9635E-03,1.0308E-02,1.9144E-02,4.9009E-02,
1      9.9575E-02,7.1627E-03,9.9575E-02,4.9009E-02,
2      1.9144E-02,3.5343E-03,8.2467E-03,1.6258E-02,
3      1.6258E-02,6.5047E-03,7.5006E-03,1.6233E-02,
4      1.6179E-02,5.1051E-03,3.9270E-03,3.6458E-03,
5      4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
6      7.8540E-05/

C
C DLA IS THE CHARACTERISTIC LENGTH OF THE SURFACE FOR
C CONVECTION HEAT TRANSFER BETWEEN THE PLATE AND
C BNFL OUTER-CONTAINER OUTER SURFACES AND THE AIR
DATA DLA/5*4.2426E-01,4.7525E-03,3*1.7686E-01,
1      10*2.5400E-01,6*1.2500E-01/

C
C ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C HEAT TRANSFER BETWEEN THE PLATE AND BNFL OUTER-
C CONTAINER OUTER SURFACES AND THE AIR
DATA ICA/573,574,575,576,577,578,579,580,581,582,
1      583,584,585,586,587,588,589,590,591,592,
2      593,594,595,596,597/

C
C ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C HEAT TRANSFER BETWEEN THE PLATE AND BNFL
C OUTER-CONTAINER OUTER SURFACES AND THE AIR
DATA ISA/187,188,189,190,191,191,191,190,189,172,
1      173,174,175,176,177,178,179,180,181,181,
2      182,183,184,185,186/

C
C IGA IS THE GAS NODE NUMBER FOR CONVECTION
C HEAT TRANSFER BETWEEN THE PLATE AND BNFL
C OUTER-CONTAINER OUTER SURFACES AND THE AIR
DATA IGA/25*192/

C
C IDA DEFINES THE SURFACE ORIENTATION FOR CONVECTION
C HEAT TRANSFER BETWEEN THE PLATE AND BNFL
C OUTER-CONTAINER OUTER SURFACES AND THE AIR
C -1 = HORIZONTAL BOTTOM SURFACE (GAS BELOW SURFACE)
C 0 = VERTICAL SURFACE
C 1 = HORIZONTAL TOP SURFACE (GAS ABOVE SURFACE)
DATA IDA/5*-1,0,3*1,10*0,6*1/

C
C AIR THERMAL CONDUCTIVITY = ATK0+AHTK1*(TL+TR)+AQTK2*(TL+TR)**2
C AIR SPECIFIC HEAT = ASH0+AHSH1*(TL+TR)+AQSH2*(TL+TR)**2
C AIR VISCOSITY = AVI0+AHVI1*(TL+TR)+AQVI2*(TL+TR)**2
C AIR DENSITY = ADN0/(ADN1+T) WHERE T,TL,&TR ARE TEMPERATURES

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C
DATA ATK0/2.3991E-02/,AHTK1/3.30685E-05/,AQTK2/-3.49125E-09/
DATA ASH0/2.7625E-01/,AHSH1/2.72465E-05/,AQSH2/-1.36857E-09/
DATA AVI0/6.1474E-02/,AHVI1/1.06686E-04/,AQVI2/-7.3260E-08/
DATA ADNO/3.5308E+02/,ADN1/2.7316E+02/

C
C EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C ALL SURFACES INSIDE THE BNFL CONTAINERS TO AIR
C
C FOR DEN=6.7, I=1,42
C   DEN=4.5, I=3,42 AND PU02-SURFACE CHANGES AND DLH CHANGES
C   DEN=3.0, I=6,42 AND PU02-SURFACE CHANGES AND DLH CHANGES
C FOR FULL CONTAINER, I=18,42
C
C DO 100 I=3,42
C   TA=T(ISSH(I))+T(IGH(I))
C   TK=ATK0+TA*(AHTK1+TA*AQTK2)
C   SH=ASH0+TA*(AHSH1+TA*AQSH2)
C   VI=AVI0+TA*(AHVI1+TA*AQVI2)
C   DG=ADNO/(ADN1+0.5*TA)
C   DT=DMAX1(0.1,DABS(T(ISSH(I))-T(IGH(I))))
C   D3=DLH(I)*DLH(I)*DLH(I)
C   GR=D3*1.27094E+08*DG*DG*DT/((HDN1+T(IGH(I)))*VI*VI)
C   PR=SH*VI/TK
C   GRPR=GR*PR
C   IF (IDH(I).NE.0) THEN
C
C     HORIZONTAL SURFACE TO HELIUM NUSSELT NUMBER
C
C     IF (((IDH(I).EQ.-1).AND.(T(IGH(I)).GE.T(ISSH(I)))).OR.
1      ((IDH(I).EQ. 1).AND.(T(IGH(I)).LE.T(ISSH(I))))) THEN
C
C       HOTTER SURFACE FACING UPWARD OR
C       COLDER SURFACE FACING DOWNWARD
C
C       IF (GRPR.LT.1.0844E+07) THEN
C         F=DMIN1(5.0,0.43429*DLOG(GRPR))
C         CNU=((F-2.0)*0.54*(GRPR**0.25)
1           +(5.0-F)*0.96*(GRPR**0.20))*0.333333
C       ELSE
C         CNU=0.14*(GRPR**0.333333)
C       ENDIF
C     ELSE
C
C       COLDER SURFACE FACING UPWARD OR
C       HOTTER SURFACE FACING DOWNWARD
C
C       F=DMIN1(5.5,0.43429*DLOG(GRPR))
C       CNU=((F-2.5)*0.27*(GRPR**0.25)
1           +(5.5-F)*0.48*(GRPR**0.20))*0.333333
C     ENDIF
C   ELSE
C
C     VERTICAL SURFACE TO HELIUM NUSSELT NUMBER
C
C     IF (GRPR.LT.7.6372E+07) THEN
C       F=DMIN1(5.0,0.43429*DLOG(GRPR))
C       CNU=((F-2.0)*0.59*(GRPR**0.25))

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1           +(5.0-F)*1.05*(GRPR**0.20))*0.33333
      ELSE
          CNU=0.13*(GRPR**0.33333)
      ENDIF
  ENDIF
  G(ICH(I))=AH(I)*CNU*TK/DLH(I)
100 CONTINUE
C
C   EVALUATE THE CONVECTION HEAT TRANSFER COEFFICIENT FROM
C   THE HORIZONTAL OR VERTICAL PLATE AND BNFL OUTER-CONTAINER
C   SURFACES TO THE SURROUNDING AIR VOLUME 192
C
DO 110 I=1,25
TA=T(ISA(I))+T(IGA(I))
TK=ATK0+TA*(AHTK1+TA*AQTK2)
SH=ASH0+TA*(AHSH1+TA*AQSH2)
VI=AVI0+TA*(AHVI1+TA*AQVI2)
DG=ADN0/(ADN1+0.5*TA)
DT=DMAX1(0.1,DABS(T(ISA(I))-T(IGA(I))))
D3=DLA(I)*DLA(I)*DLA(I)
GR=D3*1.27094E+08*DG*DG*DT/((ADN1+T(IGA(I)))*VI*VI)
PR=SH*VI/TK
GRPR=GR*PR
IF(IDA(I).NE.0) THEN
C
C   HORIZONTAL SURFACE TO AIR NUSSELT NUMBER
C
IF (((IDA(I).EQ.-1).AND.(T(IGA(I)).GE.T(ISA(I)))) .OR.
1     ((IDA(I).EQ. 1).AND.(T(IGA(I)).LE.T(ISA(I))))) THEN
C
C   HOTTER SURFACE FACING UPWARD OR
C   COLDER SURFACE FACING DOWNWARD
C
IF (GRPR.LT.1.0844E+07) THEN
    F=DMIN1(5.0,0.43429*DLOG(GRPR))
    CNU=((F-2.0)*0.54*(GRPR**0.25)
1       +(5.0-F)*0.96*(GRPR**0.20))*0.33333
ELSE
    CNU=0.14*(GRPR**0.33333)
ENDIF
ELSE
C
C   COLDER SURFACE FACING UPWARD OR
C   HOTTER SURFACE FACING DOWNWARD
C
F=DMIN1(5.5,0.43429*DLOG(GRPR))
CNU=((F-2.5)*0.27*(GRPR**0.25)
1       +(5.5-F)*0.48*(GRPR**0.20))*0.33333
ENDIF
ELSE
C
C   VERTICAL SURFACE TO AIR NUSSELT NUMBER
C
IF (GRPR.LT.7.6372E+07) THEN
    F=DMIN1(5.0,0.43429*DLOG(GRPR))
    CNU=((F-2.0)*0.59*(GRPR**0.25)
1       +(5.0-F)*1.05*(GRPR**0.20))*0.33333
ELSE

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        CNU=0.13*(GRPR**0.33333)
    ENDIF
ENDIF
G(ICA(I))=AA(I)*CNU*TK/DLA(I)
110 CONTINUE
ENDD
VAB2 DATA
ENDD
VAB3 DATA
DIMENSION H(42),ISP(19)
DIMENSION AH(42),ICH(42),ISH(42),IGH(42)
DIMENSION AA(25),ICA(25),ISA(25),IGA(25)
DIMENSION VPU(55),APU(21),IS1(41),IS2(41)

C
C      AH IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR
C          CONVECTION HEAT TRANSFER BETWEEN ALL SURFACES
C          INSIDE THE BNFL CONTAINERS AND THE AIR
DATA AH/7.1534E-03,5.7241E-03,6.6005E-03,7.1313E-03,
1      7.4924E-03,4.1542E-03,3.9867E-03,1.9439E-03,
2      2.4544E-03,1.2566E-03,6.2832E-04,7.8540E-05,
3      7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
4      5.0855E-03,1.5810E-03,4.2082E-03,2.4544E-03,
5      1.2566E-03,6.2832E-04,7.8540E-05,1.5810E-03,
6      4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
7      7.8540E-05,4.7406E-03,4.2082E-03,2.4544E-03,
8      1.2566E-03,6.2832E-04,7.8540E-05,1.4954E-03,
9      2.4960E-03,4.2082E-03,2.4544E-03,1.2566E-03,
A      6.2832E-04,7.8540E-05/
C
C      ICH IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C          HEAT TRANSFER BETWEEN ALL SURFACES INSIDE THE
C          BNFL CONTAINERS AND THE AIR
DATA ICH/124,125,126,127,128,129,130,075,074,073,
1      072,071,041,042,043,044,045,289,290,291,
2      292,293,294,308,309,310,311,312,313,437,
3      438,439,440,441,442,458,459,460,461,462,
4      463,464/
C
C      ISH IS THE SURFACE NODE NUMBER FOR CONVECTION HEAT
C          TRANSFER BETWEEN ALL SURFACES INSIDE THE BNFL
C          CONTAINERS AND THE AIR
DATA ISH/080,081,082,083,084,085,087,087,088,089,
1      090,091,061,062,063,064,065,086,087,088,
2      089,090,091,127,128,129,130,131,132,127,
3      128,129,130,131,132,180,181,182,183,184,
4      185,186/
C
C      IGH IS THE AIR NODE NUMBER FOR CONVECTION HEAT
C          TRANSFER BETWEEN ALL SURFACES INSIDE THE BNFL
C          CONTAINERS AND THE AIR
C          (AIR NODES FROM THE PATHS IN ICH)
DATA IGH/025,030,035,040,045,050,055,055,054,053,
1      052,051,031,032,033,034,035,104,105,106,
2      107,108,109,104,105,106,107,108,109,151,
3      152,153,154,155,156,151,151,152,153,154,
4      155,156/
C
C      AA IS THE HEAT-TRANSFER AREA OF THE SURFACE NODE FOR

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C      CONVECTION HEAT TRANSFER BETWEEN THE PLATE AND
C      BNFL OUTER-CONTAINER OUTER SURFACES AND THE AIR
C      DATA AA/1.9635E-03,1.0308E-02,1.9144E-02,4.9009E-02,
1      9.9575E-02,7.1627E-03,9.9575E-02,4.9009E-02,
2      1.9144E-02,3.5343E-03,8.2467E-03,1.6258E-02,
3      1.6258E-02,6.5047E-03,7.5006E-03,1.6233E-02,
4      1.6179E-02,5.1051E-03,3.9270E-03,3.6458E-03,
5      4.2082E-03,2.4544E-03,1.2566E-03,6.2832E-04,
6      7.8540E-05/
C
C      ICA IS THE HEAT-TRANSFER PATH NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN THE PLATE AND BNFL OUTER-
C      CONTAINER OUTER SURFACES AND THE AIR
C      DATA ICA/573,574,575,576,577,578,579,580,581,582,
1      583,584,585,586,587,588,589,590,591,592,
2      593,594,595,596,597/
C
C      ISA IS THE SURFACE NODE NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN THE PLATE AND BNFL
C      OUTER-CONTAINER OUTER SURFACES AND THE AIR
C      DATA ISA/187,188,189,190,191,191,191,190,189,172,
1      173,174,175,176,177,178,179,180,181,181,
2      182,183,184,185,186/
C
C      IGA IS THE GAS NODE NUMBER FOR CONVECTION
C      HEAT TRANSFER BETWEEN THE PLATE AND BNFL
C      OUTER-CONTAINER OUTER SURFACES AND THE AIR
C      DATA IGA/25*192/
C
C      VPU IS THE VOLUME OF ALL THE PU02 NODES
C
C      DATA VPU/1.4530E-06,1.1624E-05,2.3248E-05,4.5406E-05,
1      7.2983E-05,1.6258E-06,1.3006E-05,2.6012E-05,
2      5.0805E-05,1.0527E-04,1.6258E-06,1.3006E-05,
3      2.6012E-05,5.0805E-05,1.0527E-04,1.6258E-06,
4      1.3006E-05,2.6012E-05,5.0805E-05,1.0527E-04,
5      1.6258E-06,1.3006E-05,2.6012E-05,5.0805E-05,
6      1.0527E-04,1.3009E-06,1.0407E-05,2.0815E-05,
7      4.0654E-05,8.4235E-05,1.5001E-06,1.2001E-05,
8      2.4002E-05,4.6878E-05,9.7132E-05,1.6207E-06,
9      1.2966E-05,2.5932E-05,5.0648E-05,1.0494E-04,
A      1.6258E-06,1.3006E-05,2.6012E-05,5.0805E-05,
B      8.6653E-05,1.1074E-06,8.8593E-06,1.7719E-05,
C      3.4607E-05,2.8311E-05,1.1074E-06,8.8593E-06,
D      1.7719E-05,3.4607E-05,2.7408E-05/
C
C      APU IS THE SURFACE AREA OF THE OUTSIDE PU02 NODES
C
C      DATA APU/7.8540E-05,6.2832E-04,1.2566E-03,2.4544E-03,
1      3.8021E-03,4.9447E-03,4*7.1534E-03,5.7241E-03,
2      6.6005E-03,7.1313E-03,7.4924E-03,4.1542E-03,
3      3.9867E-03,1.9439E-03,2.4544E-03,1.2566E-03,
4      6.2832E-04,7.8540E-05/
C
C      IS1 IS THE RADIATION-PATH CONTAINER OUTER SURFACE NUMBER
C      IS2 IS THE RADIATION-PATH EXT. AND PLATE SURFACE NUMBER
C
C      DATA IS1/4*172,4*173,4*174,4*175,4*176,3*177,3*178,

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1           3*179,3*180,4*181,182,183,184,185,186/
1           DATA IS2/189,190,191,192,189,190,191,192,189,190,
1           191,192,189,190,191,192,189,190,191,192,
2           190,191,192,190,191,192,190,191,192,190,
3           191,192,190,191,7*192/
C
C     ISP DEFINES THE PUO2 SURFACE NUMBER NUMBERS
C
C     DATA ISP/001,002,003,004,005,010,015,020,025,030,
1           035,040,045,050,055,054,053,052,051/
C
C     BACK CALCULATE HTC USED AT SELECTED GAS/SURFACE PATHS
C     INSIDE THE BNFL CONTAINER
C
        DO 99 I=1,42
        H(I) = 0.0
99    CONTINUE
        DO 100 I=3,42
        H(I)=G(ICH(I))/AH(I)
100   CONTINUE
        WRITE(6,110)
110   FORMAT('/[H.T.PATH] HEAT-TRANSFER COEFFICIENT (W/M**2/C)')
        WRITE(6,120) (ICH(I),H(I),I=1,42)
120   FORMAT(' [',I3,']=',F8.4,' [',I3,']=',F8.4,' [',I3,']=',
1           F8.4,' [',I3,']=',F8.4,' [',I3,']=',F8.4)
C
C     EVALUATE THE HEAT FLOWS AND TEMPERATURES FROM THE PUO2
C
        QCDB=0.0
        DO 130 I=1,5
        QCDB=QCDB+G(I)*(T(I)-T(I+70))
130   CONTINUE
C
C     FOR DEN=6.7, I=1,4
C     FOR DEN=4.5, I=1,6
C     FOR DEN=3.0, I=1,9
C     FOR FULL CONTAINER, I=1,11
C
        QCDS=0.0
        DO 140 I=1,6
        J = I+75
        IF (I.EQ.11) J=I+76
        QCDS=QCDS+G(I+119)*(T(5*I)-T(J))
140   CONTINUE
        QCDT=0.0
        QCD=QCDB+QCDS+QCDT
        QCVB=0.0
        QCVS=0.0
C
C     FOR DEN=6.7, I=26,30
C     FOR DEN=4.5, I=41,45 AND 30=>20 AND -5=>-10
C     FOR DEN=3.0, I=61,65 AND 30=>25 AND -5=>15
C     FOR FULL CONTAINER, QCDT RATHER THAN QCVT IS DEFINED
C
        QCVT=0.0
        DO 150 I=41,45
        QCVT=QCVT+G(I)*(T(I+20)-T(I-10))
150   CONTINUE

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QCV=QCVT
C
C      QRDB=0.0
C      QRDS=0.0
C      IN THE FOLLOWING DO LOOP (DO 160), THE FIRST
C      T IN EACH T**4 DIFFERENCE SHOULD BE FOR NODES ---
C          FOR DEN=6.7, 56-60;
C          FOR DEN=4.5, 61-65;
C          FOR DEN=3.0, 66-70;
C          FOR DEN<=2.7, DOESN'T MATTER.
C      THIS WORKS BECAUSE THE G(I)=0 FOR NON-APPLICABLE
C      PATHS. G(I)=0 WHEN EMISSIVITY AND/OR AREA IS ZERO.
C      QRDT=0.0
C      DO 160 I=131,141
C          J = I-51
C          IF (I.EQ.137) J=I-50
C          QRDT=QRDT+G(I)    *((T(61)+273.16)**4
C          1           -(T(J)+273.16)**4)
C          2           +G(I+11)*((T(62)+273.16)**4
C          3           -(T(J)+273.16)**4)
C          4           +G(I+22)*((T(63)+273.16)**4
C          5           -(T(J)+273.16)**4)
C          6           +G(I+33)*((T(64)+273.16)**4
C          7           -(T(J)+273.16)**4)
C          8           +G(I+44)*((T(65)+273.16)**4
C          9           -(T(J)+273.16)**4)
160  CONTINUE
      QRD=QRDT
      TOT=QCD+QCV+QRD
      FCD=QCD/TOT
      FCDB=QCDB/TOT
      FCDS=QCDS/TOT
      FCDT=QCDT/TOT
      FCV=QCV/TOT
      FCVB=QCVB/TOT
      FCVS=QCVS/TOT
      FCVT=QCVT/TOT
      FRD=QRD/TOT
      FRDB=QRDB/TOT
      FRDS=QRDS/TOT
      FRDT=QRDT/TOT
      WRITE(6,170) QCD,QCDB,QCDS,QCDT,
      1           QCV,QCVB,QCVS,QCVT,
      2           QRD,QRDB,QRDS,QRDT,
      3           TOT,
      4           FCD,FCDB,FCDS,FCDT,
      5           FCV,FCVB,FCVS,FCVT,
      6           FRD,FRDB,FRDS,FRDT
170  FORMAT(/' HEAT TRANSFER FROM THE PU02 OUTER SURFACE'/
      1           ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
      2           ' W, QCDB =',F10.6,' W'/' QCV =',F10.6,' W, QCDB =',
      3           F10.6,' W, QCDS =',F10.6,' W, QCDB =',F10.6,' W'/
      4           ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
      5           ' W, QRDB =',F10.6,' W'/' TOT =',F10.6,' W'//
      6           ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
      7           ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
      8           ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
      9           ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',

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      A          F10.6)
C
      TMX=0.0
      TMN=1000.0
      TAV=0.0
      VS=0.0
C
      I=1,20 FOR DEN=6.7
      I=1,30 FOR DEN=4.5
      I=1,45 FOR DEN=3.0
      I=1,55 FOR FULL CONTAINER
C
      DO 180 I=1,30
      IF (T(I).GT.TMX) THEN
          IMX=I
          TMX=T(I)
      ENDIF
      IF (T(I).LT.TMN) THEN
          IMN=I
          TMN=T(I)
      ENDIF
      TAV=TAV+VPU(I)*T(I)
      VS=VS+VPU(I)
180  CONTINUE
      TAV=TAV/VS
      TMXF=TMX*1.8+32.0
      TMNF=TMN*1.8+32.0
      TAVF=TAV*1.8+32.0
      WRITE(6,190) TMX,TMXF,IMX,TMN,TMNF,IMN,TAV,TAVF
190  FORMAT(/' PUO2-VOLUME TEMPERATURES'/
     1         ' TMX = ',F9.4,' C = ',F9.4,' F AT NODE',I4/
     2         ' TMN = ',F9.4,' C = ',F9.4,' F AT NODE',I4/
     3         ' TAV = ',F9.4,' C = ',F9.4,' F')
C
      TMX=0.0
      TMN=1000.0
      TAV=0.0
      AS=0.0
C
      I=1,8 FOR DEN=6.7 (USE 55 IN DO LOOP 210)
      I=1,10 FOR DEN=4.5 (USE 60 IN DO LOOP 210)
      I=1,13 FOR DEN=3.0 (USE 65 IN DO LOOP 210)
      I=1,19 FOR FULL CONTAINER (DELETE DO LOOP 200)
C
      DO 200 I=1,10
      IF (T(ISP(I)).GT.TMX) THEN
          IMX=ISP(I)
          TMX=T(IMX)
      ENDIF
      IF (T(ISP(I)).LT.TMN) THEN
          IMN=ISP(I)
          TMN=T(IMN)
      ENDIF
      TAV=TAV+APU(I)*T(ISP(I))
      AS=AS+APU(I)
200  CONTINUE
      DO 210 I=1,5
      IF (T(I+60).GT.TMX) THEN

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        IMX=I+60
        TMX=T( IMX )
    ENDIF
    IF (T(I+60).LT.TMN) THEN
        IMN=I+60
        TMN=T( IMN )
    ENDIF
    AAAA=APU(I)
    IF(I.EQ.5) AAAA=5.0855E-03
    TAV=TAV+AAAA*T(I+60)
    AS=AS+AAAA
210 CONTINUE
    TAV=TAV/AS
    TMXF=TMX*1.8+32.0
    TMNF=TMN*1.8+32.0
    TAVF=TAV*1.8+32.0
    WRITE(6,220) TMX,TMXF,IMX,TMN,TMNF,IMN,TAV,TAVF
220 FORMAT('/ PUO2-SURFACE TEMPERATURES'
1      ' TMX = ',F9.4,' C = ',F9.4,' F AT NODE',I4/
2      ' TMN = ',F9.4,' C = ',F9.4,' F AT NODE',I4/
3      ' TAV = ',F9.4,' C = ',F9.4,' F' )

C
    QCDB=0.0
    QCDS=0.0
    QCDT=0.0
    J=187
    DO 230 I=563,568
    IF (I.EQ.566) J=188
    QCDB=QCDB+G(I)*(T(I-397)-T(J))
230 CONTINUE
    QCD=QCDB
    QCV=0.0
    QCVB=0.0
    DO 240 I=573,597
    IF (I.GE.582) THEN
        J=I-410
        IF (I.GE.592) J=J-1
        QCV=QCV+G(I)*(T(J)-T(192))
        IF (I.EQ.592) QCVS=QCV
    ENDIF
    H(I-572)=G(I)/AA(I-572)
240 CONTINUE
    QCVT=QCV-QCVS
    WRITE(6,110)
    WRITE(6,120) (I,H(I-572),I=573,597)
    QRD=0.0
    QRDB=0.0
    DO 250 I=607,647
    QRD=QRD+G(I)*((T(IS1(I-606))+273.16)**4
1           -(T(IS2(I-606))+273.16)**4)
    IF (I.EQ.641) QRDS=QRD
250 CONTINUE
    QRDT=QRD-QRDS
    TOT=QCD+QCV+QRD
    FCD=QCD/TOT
    FCDB=QCDB/TOT
    FCDS=QCDS/TOT
    FCDT=QCDT/TOT

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FCV=QCV/TOT
FCVB=QCVB/TOT
FCVS=QCVS/TOT
FCVT=QCVT/TOT
FRD=QRD/TOT
FRDB=QRDB/TOT
FRDS=QRDS/TOT
FRDT=QRDT/TOT
WRITE(6,260) QCD,QCDB,QCDS,QCDT,
1           QCV,QCVB,QCVS,QCVT,
2           QRD,QRDB,QRDS,QRDT,
3           TOT,
4           FCD,FCDB,FCDS,FCDT,
5           FCV,FCVB,FCVS,FCVT,
6           FRD,FRDB,FRDS,FRDT
260 FORMAT(/' HEAT TRANSFER FROM THE BNFL-CONTAINER SURFACE'/
1       ' QCD =',F10.6,' W, QCDB =',F10.6,' W, QCDS =',F10.6,
2       ' W, QCDT =',F10.6,' W'/' QCV =',F10.6,' W, QCVB =',
3       F10.6,' W, QCVS =',F10.6,' W, QCVT =',F10.6,' W'/
4       ' QRD =',F10.6,' W, QRDB =',F10.6,' W, QRDS =',F10.6,
5       ' W, QRDT =',F10.6,' W'/' TOT =',F10.6,' W'//
6       ' FCD =',F10.6,' , FCDB =',F10.6,' , FCDS =',F10.6,
7       ' , FCDT =',F10.6,' FCV =',F10.6,' , FCVB =',F10.6,
8       ' , FCVS =',F10.6,' , FCVT =',F10.6,' FRD =',F10.6,
9       ' , FRDB =',F10.6,' , FRDS =',F10.6,' , FRDT =',
A       F10.6)
C
TMX=0.0
TMN=1000.0
TAV=0.0
ARW=0.0
DO 270 I=166,171
IF (T(I).GT.TMX) THEN
  IMX=I
  TMX=T(I)
ENDIF
IF (T(I).LT.TMN) THEN
  IMN=I
  TMN=T(I)
ENDIF
TAV=TAV+AA(191-I)*T(I)
ARW=ARW+AA(191-I)
270 CONTINUE
DO 280 I=172,186
IF (T(I).GT.TMX) THEN
  IMX=I
  TMX=T(I)
ENDIF
IF (T(I).LT.TMN) THEN
  IMN=I
  TMN=T(I)
ENDIF
J=I-162
IF (I.GE.182) J=J+1
TAV=TAV+AA(J)*T(I)
ARW=ARW+AA(J)
280 CONTINUE
TAV=TAV/ARW

```

```
TMXF=TMX*1.8+32.0
TMNF=TMN*1.8+32.0
TAVF=TAV*1.8+32.0
WRITE(6,290) TMX,TMXF,IMX,TMN,TMNF,IMN,TAV,TAVF
290 FORMAT(/' BNFL-CONTAINER OUTER-SURFACE TEMPERATURES'/
1      ' TMX =',F9.4,' C =',F9.4,' F AT NODE',I4/
2      ' TMN =',F9.4,' C =',F9.4,' F AT NODE',I4/
3      ' TAV =',F9.4,' C =',F9.4,' F' )
ENDD
USER DATA
ENDD
ENDD
```